

THE HAWAIIAN PLANTERS' RECORD

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The Growth of the Sugar Cane Plant Sugar planters have always recognized climate as a definite asset and have known that the different seasons of the year vary widely in their effects upon cane growth. Recently attempts have been made to place mathematical ratings on the different months, in order to show their relative values from a cane or sugar production standpoint.

Tables were compiled two years ago by J. A. Verret and W. P. Alexander, based on cane growth measurements covering several years at Ewa Plantation. Parallel columns showed the elongation of the stalk in inches as measured each month, and alongside of this a percentage figure denoted what part of the total crop this stalk growth represented. For instance, in short ratoon cane of fourteen months growth, we find these values:

	Increased length of well developed stalk in inches	Part of crop repre- sented in each month's cane meas- urements
March	8.5	5.8%
April	9.0	6.1
May	11.5	7.8
June	13.9	9.5
July	13.8	9.4
August	17.0	11.6
September	15.8	10.7
October	15.9	10.8
November	13.5	9.2
December	8.3	5.7
January	6.0	4.1
February	4.6	3.1
March	4.5	3.1
April	4.6	3.1

At the suggestion of Mr. Alexander, we are now considering additional tables which will take due account of how and when the weather of a given month is registered in stalk growth. The part of the cane stalk that is in

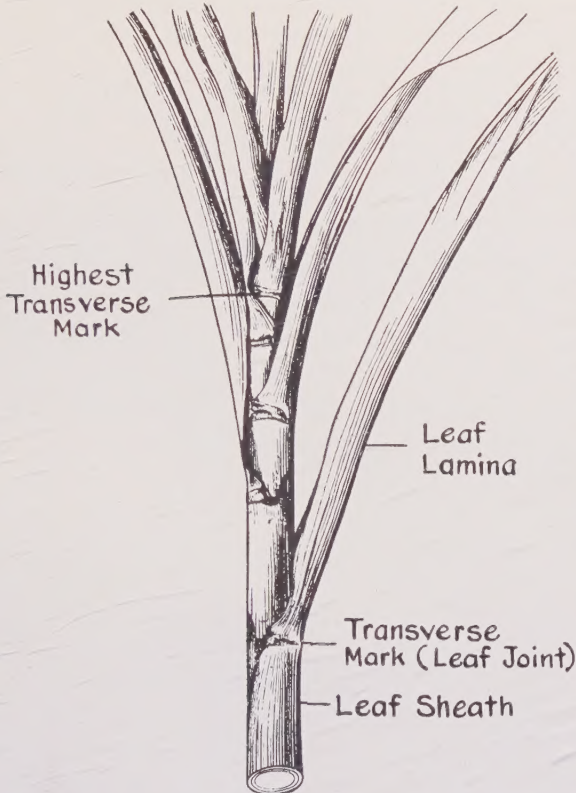
process of elongation is the immature portion that is encased in the growing top. Such growth as is caused by the weather of June, for instance, is not exhibited as fully formed cane stalk until several weeks later. We are inclined to believe that the maximum growth measured in August was actually caused in June, or thereabouts. The high point in cane growth under Oahu conditions would then coincide more nearly with the season of greatest daylight instead of the period of highest mean temperatures. The lowest rate of growth would be expected in December. Cane planters are frequently impressed by the fine appearance of cane in September, when new, long joints appear. This growth took place, probably, in July and becomes visible two months later when the tightly encased leaf-sheaths loosen and fall apart. In September the growth is checked somewhat abruptly, as a result of which, tassels are formed at the growing tip. These tassels make their appearance fully developed in November.

In studying this question a great amount of help can be had from a paper by C. A. Barber, for he throws much light on the subject by recording the observations of others who give us new and definite information on the process of cane growth. The dissection of cane tops in connection with the information presented by Mr. Barber serves to confirm the observations that have led Mr. Alexander to suggest the construction of additional tables that will show for each month the cane growth brought about by the climatic environment (temperature and daylight hours) of that particular period. We read from Mr. Barber's paper: *

One of the greatest difficulties in measuring growing canes is due to the fact that the portion in actual elongation is permanently enswathed in a mass of leaves which cannot be removed without disturbing the growth. Observation of the ends of these leaves cannot be used in measurement because of the constant variation in length of successive leaves during the growing period. It becomes necessary to find some definite external point on the shoot which bears a constant relation to the growing point of the stem within. Kamerling set himself to find such a point. His object was to study the rate of growth in different fields and varieties and to replace the general terms in use, such as "rapid," "slow," "moderately slow," and so on, by exact measurements, at the same time pointing out the importance of such work for the factory. By determining the rate of growth under certain well defined conditions, he claimed that we should be in a position not only to decide the fitness of a variety for its locality, but also to fix on general measures whereby unsatisfactory growth might be remedied. He first of all found that there is a sequence of growth in length in the lamina, leaf sheath and stem of a very definite character. The lamina first grows in length, rapidly unfolds itself and ceases from any further increase; as soon as this is completed, the energy of growth is transferred to the sheath. It quickly elongates and pushes the lamina into the air and light, and in its turn ceases from further growth in length. Lastly, when the leaf sheath has finished growing, the stem internodes, hitherto merely a series of flat, superposed discs, suddenly elongate by the expansion of their cells and cease to grow in length after a very short time. The sheaths thus complete their growth in length before the internodes commence to elongate, and their further apparent growth is due to the increase in length of the internodes to which they are attached. In the young shoot each leaf sheath is entirely covered by the one outside it, while it is yet undeveloped, but the moment when it emerges from this protection Kamerling shows to coincide with its cessation of growth. The tops of two successive sheaths are now close together, and any

* *Memoirs of the Department of Agriculture in India, Botanical Series, Vol. X, page 156.*

further separation is due to extension of the stem which at this period commences to elongate. The top of the leaf sheath is the place where it joins the lamina, and Kamerling selected this point, which he calls the "blad-gewricht" (leaf joint), as the one by the observation of which he could indirectly observe the growth in length of young joints of the stem apex (see Figure).



This demonstration of Kamerling's has been found to be justified, on the assumption that all of the mature leaf sheaths are of equal length. He measured a series of leaf sheaths in different canes and soon found that, while the differences in their length in fully grown parts of the cane plant were very small, both at the beginning and end of the vegetative season the leaf sheaths were of different sizes. The first sheaths are very small, these successively increase in length until they reach a fairly uniform maximum, and this is maintained during active growth. Towards the end of the season, however, the sheaths again diminish in length. He made a distinction between the actual growth of the young internodes and their "apparent" growth, as judged by the observation of the leaf joint, and showed that, while the difference between the actual and apparent growth is small during the period of full growth of the cane plant, it is large at the beginning and end of the season. Kamerling then tried a method of measuring the

growth of the stem directly, by removing the leafy mass around the actively elongating portion, marking it and covering it with tin foil, and measuring it again after twenty-four hours. The results agreed with those already obtained, showed that the region of elongation was confined to few joints, and that, in these the top of each joint ceased growing first and the lower part continued elongating after the upper had ceased to alter, that is, that the region of most active growth in length in each joint was basipetal. But such harsh treatment of the young growing parts soon introduced irregularities in development, and Kamerling's main results depended on the indirect method mentioned above.

To Kuijper belongs the credit of overcoming once and for all these difficulties. After trying various methods, he hit upon the ingenious plan of piercing the whole growing shoot with a darning needle (finer instruments encountered too much resistance), starting with a full-grown leaf sheath on the outside, which showed no further movement, and working upwards. A series of holes were thus made through the whole mass of growing parts, and, as growth took place, these holes were pushed up in various degrees in the different organs inside. After a period of six days the relative position of the holes was studied, and their change in position gave an accurate measure of the growth which had taken place in each organ. By multiplication of the initial holes at distances of about one centimetre up the outer leaf sheath, he was able to state definitely in what part of each organ growth was most rapid, as all that remained to be done was to dissect

out the mass after a stated interval, lay out the parts, and measure the vertical distances between the holes. While this method was found to disturb the growth in very young parts, it fully justified its use, and the general results obtained by Kamerling were substantiated, but, by a series of *actual*, in place of *inferred*, measurements. The basi-petal tendency of the zone of most active growth in each internode was confirmed, and it was found that the leaf sheath and lamina behaved in a similar manner. Kuijper's work was, in the main, instituted for a study of certain diseases of the shoot, which appeared to depend on the relative growth of the young parts, and the previous work of Kamerling did not give the accurate figures required for this. He fully endorsed the selection of the upper most visible leaf joint for measurement in stem growth, safeguarding it, as was done by Kamerling, at the beginning and end of the season. We are indebted to him for the first clear demonstration of what goes on inside the growing portion of the cane shoot.

Yield of Sugar in the Territory of Hawaii for Crop of 1921.

	Acres	Tons Sugar Harvested	Lbs. Sugar per Acre	Tons Sugar per Acre
Total yield	119,854.77	564,562.2505	9,420	4.710
Irrigated plantations	63,686.01	350,199.2360	10,998	5.499
Unirrigated plantations..	56,168.76	214,363.0145	7,632	3.816
Hawaii	54,303.76	208,522.8470	7,680	3.840
Oahu	23,142.08	130,972.3780	11,318	5.659
Kauai	23,120.93	108,037.5850	9,346	4.673
Maui	19,288.00	117,029.4405	12,134	6.067

Mites and Other Organisms in Their Possible Relation to Sugar Cane Root-rot in Hawaii.

By C. E. PEMBERTON.

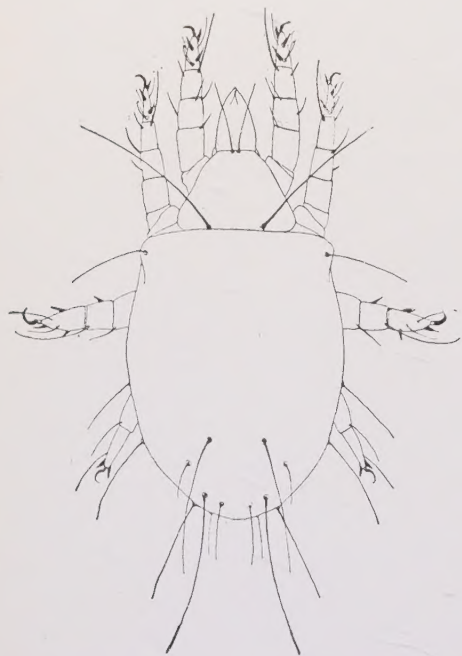
During recent root investigations in diseased cane at Grove Farm and Honokaa plantations, Dr. L. O. Kunkel observed extensive injury to live roots of a type which appeared to be entirely apart from fungus infection. Roots were badly perforated with holes which he suspected were made by something in the nature of a worm. The holes were so numerous and the injured roots so generally distributed in the diseased areas that he concluded that the "worm injury" could alone readily account for and be the "primary cause" of Root-rot in these fields. Dr. Kunkel's remarks,* in part, respecting this injury, were as follows:

The dead and dying roots of the ratoon cane are infected with several different undetermined fungi. There can be no doubt but that these organisms are capable of causing Root-rot after they have once entered the tissues. Whether or not they are able to attack sound roots is not known. They seem to enter the roots through what appear to be *small worm-holes*. Worms were not actually found in the roots. The injury is similar to that which has been observed at Honokaa, and which is suspected of bringing about Root-rot troubles there. In some of your ratoon fields, for example Field 15, practically every root is more or less worm eaten. Through the wounds made by the worms, various parasites (fungi) enter and destroy the tissues. It is our opinion that the worm-injury is the primary cause of Root-rot in these fields. For some reason the worms do very little damage to the roots of plant cane.

With the object of locating if possible the insect, worm, or other organism, which might be making the many holes in the roots which Dr. Kunkel recorded, a careful examination was made among roots in poorly-growing ratoon cane at Kukuihaele and in plant and ratoon cane at Honokaa. Such root conditions as

* Letter to E. H. W. Broadbent, Manager Grove Farm Plantation, Lihue, Kauai, dated April 5, 1922.

Dr. Kunkel described were immediately found. Holes of varying shape and size were exceedingly abundant both in tender, growing roots, all the way from the tip to the base; scattered through most of the dead roots; and particularly common in the small roots just starting. Frequently entire ends of a young vigorous root were completely hollowed out. The root-injury can be found both in young and mature plant cane, and in ratoons. The holes in the roots vary generally from one-half to one millimeter ($1/50$ th to $1/25$ th in.) in diameter, are more or less circular, may be shallow or penetrate to the central cylinder of the root or sometimes go clear through. They frequently occur at the very growing tip. Similar root-injury was commonly found in Lahaina and H 109 cane on Honolulu Plantation at Puuloa and in the same varieties at Ewa Plantation. Such injury can seriously handicap the growth of the cane, when the majority of the roots are punctured, as is frequently the case.



A species of mite (*Rhizoglyphus rhizophagus*), highly magnified, which is related to one found in Hawaiian soils. (Reproduced from "A Treatise on the Acarina, or Mites," by Nathan Banks of the Smithsonian Institution.)

At Honokaa, a minute brownish mite was several times actually found in the freshly-made holes in tender, growing roots, and further search revealed it present wherever the typical root-injury occurred. Owing to its minute size and brownish color, it was at first easily overlooked. One cane eye just beneath the surface of the ground was found under which a number of these mites were clustered. Considerable of the rind-tissue, where they were gathered, had been eaten. It did not appear to be bud-moth work and distinctly not wire-worm injury. Similar mites were also found present among the roots of the injured cane at Puuloa and at Ewa.

It is yet too early to state definitely the part played by mites and other animal organisms in the formation of these root-holes. The injury has most likely been going on for a long time. The clean-cut holes and gashes in the roots are of such a definite

character and so similar in all cane examined, that it is probable that only one type of organism is particularly responsible for most of the damage. Several minor factors may also contribute to the injury, however, for newly budding roots at or very close to the surface are sometimes found with holes and cuts in them that are larger than the characteristic perforations in an average root. The fauna of our cane soils, though very inconspicuous in general, is fairly rich. Among the possible cane-root feeders may be mentioned the numerous nematodes, whose relations to the cane are mostly unknown; Acari, or mites, in

abundance; ants of several species, present in enormous numbers and penetrating wherever cane-roots will go; and active Crustaceans, living mostly on organic matter. A minute snail has also fallen under suspicion. One mite, as discussed above, has already been seen at work. Its real importance has yet to be determined. F. Muir and O. H. Swezey have just found that one of the Crustaceans, a common sow-bug or wood-louse, will eat holes in cane-roots when placed with them in confinement, and two of the known nematodes have long been recorded as cane-root feeders, though they do not cause such holes in the cane-roots as discussed herein. It is quite possible that ants may bite into tender cane-roots when encountered during their intricate ramifications in the soil, in, under and about the cane-stools. It would be wholly within their general habits though their actual dependence on roots for food is not likely.

The mites conspicuously present among the injured roots will need careful study. Their general distribution in cane from the top to the bottom of the stools, everywhere accompanying the injury, throws much suspicion upon them. Certain mites have had a black history. Many are known to be destructive to plants and the food of animals and man and some are particularly injurious to the roots of plants. The family *Tyroglyphidae* contains species of economic importance. They particularly attack stored foods and the bulbs and roots of plants. Most of them feed upon vegetable matter. Nathan Banks, the foremost American authority on the Acarina, or mites, states that the *Tyroglyphidae* feed upon "cheese, flour, hams, dried meats, hair in furniture, cereals, many drugs, dried fruits, seeds of all kinds, bulbs, feathers, hay and entomological specimens." He states that in Europe one species lives in mushrooms and spreads disease that causes the decay of the pileus (the upper part). An American species of the same family is also said to be highly destructive to growing mushrooms. The bulb mite *Rhizoglyphus hyacinthi* is recognized as an important bulb-pest and is said by Banks to be "responsible for an enormous amount of damage," and that "in Europe it has lately been proved that this, or an allied species, does great damage to the roots of grape-vines." He further states that it can be controlled by the use of carbon-bisulphide injected into the soil above the infested roots. Other species of the same genus are injurious to the stems of carnations and the roots of asparagus.

The recognition of this extensive root-injury thus opens a new field for biologic investigation in the Hawaiian cane fields and promises to be an important one. The determination of the causes and the application of successful control methods to prevent such damage, may solve many so-called soil problems and explain the poor condition of much cane which often fails to respond to elaborate processes of cultivation and fertilization.

Fig Trees for Hawaiian Forests.

BY H. L. LYON
(Concluded from page 87.)

THE BANYAN

Among the fig trees already present in Hawaii, the banyan, *Ficus Bengalen-sis*, is easily the most striking novelty. It is a rapidly growing tree which quickly attains large dimensions. In its native haunts in India, single banyan trees are said to occupy more space than any other known tree. A specimen with a crown over 2,000 feet in circumference has been recorded and trees with crowns 300 to 500 feet in diameter are not uncommon. From a central trunk which attains large size, the banyan throws out massive horizontal branches which send down to the ground at intervals aerial roots which eventually become secondary trunks. In this manner the tree virtually walks over the landscape producing an enormous dome of dense foliage supported on numerous column-like trunks.

The banyan is a natural component of the forests throughout India, extending down to sea level in the south and up to 4,000 feet elevation in the north. It can endure prolonged droughts and survive severe frosts, but under the first named condition it usually drops most of its leaves, and under the last named, it may lose all of them. The tree is notoriously hardy, submitting indefinitely to the most severe mutilation. It is highly esteemed in all parts of India and is extensively planted for shade in villages and along roadsides. The leaves and young branches constitute a choice fodder for elephants and are much used for this purpose, the felling of a banyan being prohibited by law within a certain radius about the recognized camping grounds of elephant trains, in order to insure an adequate supply of fodder for the beasts.

The leaves of the banyan are large, ovate, or elliptic and rather thick and coarse. The fruits are pubescent, 1/2 to 3/4 inch in diameter and bright scarlet when ripe. In India these fruits are freely eaten by birds, bats and monkeys, and on occasion by human beings.

We have located sixty-seven fruiting specimens of the banyan in Honolulu and doubtless a careful search would reveal many more. All visitors to our city are much impressed by the splendid banyans in the grounds of the executive and judiciary buildings and all kamaainas are familiar with the magnificent specimen in the public square at Lahaina.

The foliage of the local trees is often covered with a black sooty-mold that grows on the excretion of a mealy bug which feeds on the leaves and young twigs. This same mealy bug injures the foliage and fruit of the cultivated fig, *Ficus carica*, and is the most serious pest attacking the leaves of the avocado. It also infests other economic plants. The Board of Commissioners of Agriculture and Forestry has recently undertaken to find and introduce into Hawaii

parasites and predators which will prey upon this troublesome insect. During the past few months, H. T. Osborn, who is doing the field work on this project, has sent over from Mexico several mealy-bug-destroying insects which promise to establish themselves here. It is to be expected, therefore, that within a few years the sooty-mold will be far less prevalent on our banyans than it is at the present time, due to the reduction of the mealy bug by its natural enemies.



Fig. 7. *Ficus Benghalensis*. The aerial root system of one of the big banyans in the grounds of the Executive building in Honolulu.

The banyan might easily be used to very good advantage in the protection of our old forests and in the creation of new forests on our watersheds. It should be of particular value as a component of the lower barrier forests. It produces all by itself an excellent cover which can successfully withstand heavy winds, floods and droughts as occasions demand. On steep slopes it would prove an effective soil binder, preventing land slides and gulching. The introduction of the wasp peculiar to *Ficus Benghalensis* has not been approved by the Board of Commissioners of Agriculture and Forestry.

THE CHINESE BANYAN

The fig tree, *Ficus retusa*, which is locally known as the Chinese banyan, is a natural component of the vast forests of the sub-Himalayan tract in northern India and Burma, but it also extends through southern China, Siam, the Malay peninsula, and onto many of the islands of the Malay archipelago. The tree was undoubtedly introduced into Hawaii from China and consequently it became known as the Chinese banyan.

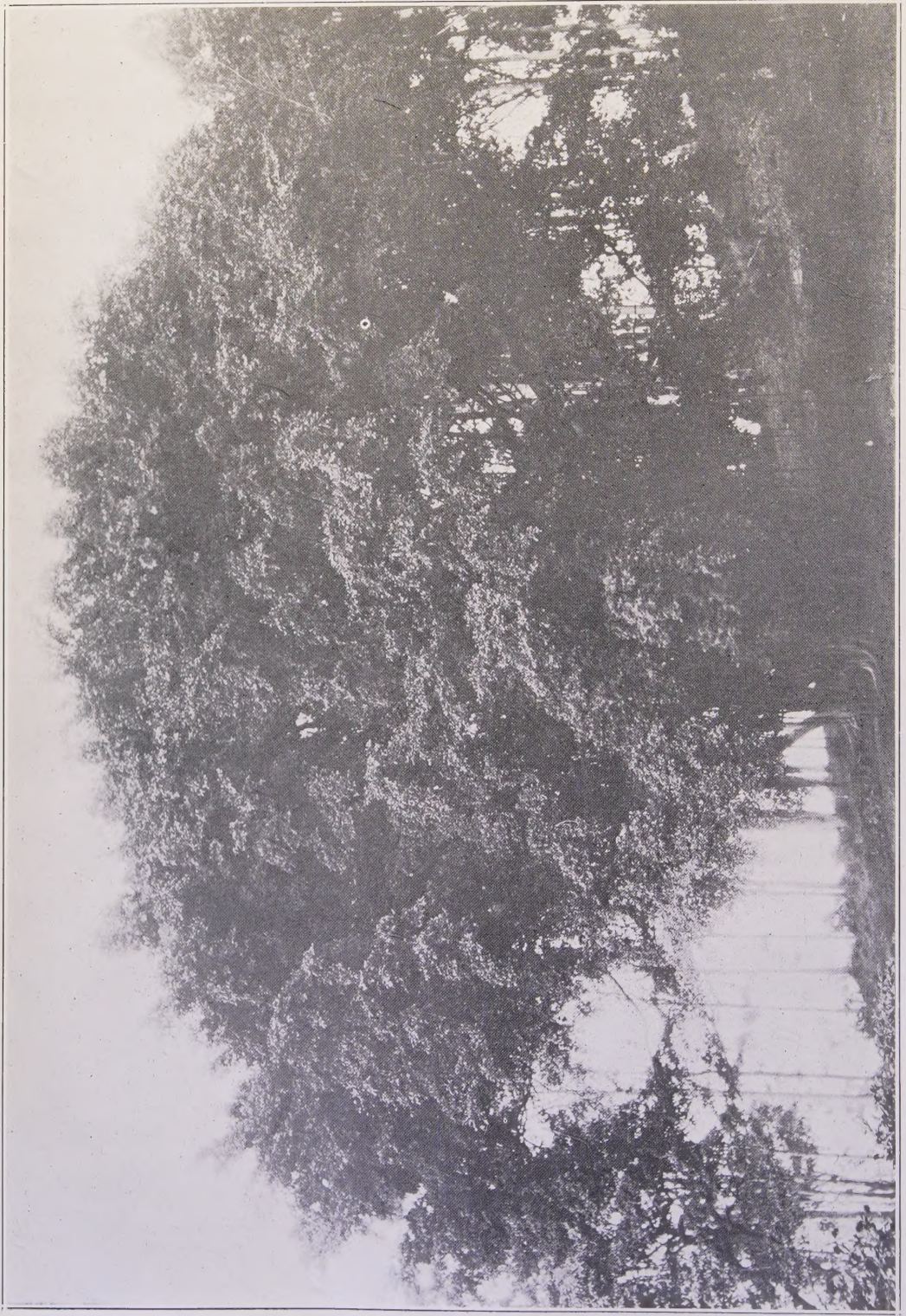


Fig. 8. *Ficus retusa*. A fine specimen of the Chinese banyan growing in the arboretum which surrounds the manager's house at Kukuihaele.

This tree is quite often planted in India for shade and ornament but it is not as popular for these purposes as are the true banyan, *Ficus Bengalensis*, and the Peepul tree, *Ficus religiosa*. In Java, however, *Ficus retusa* is a favorite tree for planting along roadsides and in public places where space is available. The Javanese often train and trim the crowns of trees of this and similar species into fantastic shapes. In the ancient town of Djogjakarta may be seen "Waringin" trees with crowns approximating in shape many of the well known geometrical figures, such as cubes, prisms, etc. *Ficus retusa* was one of the very first large growing trees to make its appearance on the island of Krakatau after the titanic volcanic eruption of 1883 had destroyed all of the vegetation on that island. Seeds of this tree were undoubtedly carried to the island by birds and the species is now represented in the new flora by several trees of large dimensions.



Fig. 9. *Ficus retusa*. An example of the non-banyanizing type. This makes an excellent shade tree for lawns and parks. The specimen here illustrated stands in Thomas Square.

The Chinese banyan, like the true banyan, is inclined to grow in the horizontal direction to a greater extent than it does in the vertical direction, but its crown often mounts to nearly or quite a hundred feet in height. If left to itself and given plenty of room it branches only a few feet above the ground and produces a compact crown of very pleasing shape. In habit it closely simulates the true banyan but is easily distinguished from the latter by its more numerous and much smaller leaves which have blades only two to four inches long as compared to the four to eight inch blades of the banyan leaves. Then the fruits of *Ficus retusa* are small, not exceeding $\frac{1}{3}$ inch in diameter, while those of *Ficus Bengalensis* are $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter. There are several varieties of the Chinese banyan, some being given to the production of drop-roots to a much greater extent than others. There are varieties like the one in Thomas Square which never produce any drop-roots at all.



Fig. 10. *Ficus Benjamina comosa*. A very picturesque specimen of the weeping fig growing in Mrs. Foster's garden. It is quite evident that the soil beneath such trees cannot be removed to any extent by water erosion.

Ficus retusa holds second place among the fig trees as an ornamental tree in Honolulu, its representatives being slightly exceeded in numbers by those of *Ficus Bengalensis*. It is a much cleaner tree than the latter under our conditions, however, for it is less severely attacked by the mealy bugs and consequently its foliage is not so commonly disfigured with sooty-mold. There are many fine specimens of the Chinese banyan in Honolulu. Some of the most accessible ones are located in Ex-Governor Carter's grounds on Judd and Liliha streets, in Mrs. Foster's yard on Nuuanu between Vineyard and School streets, in the grounds of the Lunalilo Home, and in Thomas Square. The trees in the latter situation are of the type that do not banyanize or produce drop-roots. One of these trees is illustrated in Figure 9.

We are confident that *Ficus retusa* would prove a most useful tree in our forestry work. It will survive any mutilation short of absolute elimination. It is partial to moist situations and consequently should thrive in our rain forests. Of the many fig trees to be found in northern India it is said to be by far the most frost resistant and so we may reasonably expect that it can maintain itself up to an elevation of 6,000 feet or more, or as high as we shall wish to extend our forests.

Several attempts have been made to introduce into Hawaii the wasp peculiar to *Ficus retusa* but although insects in one or two consignments arrived in a living condition, they have failed to establish their race in local trees. There are many fruiting specimens of the Chinese banyan on the island of Hong Kong and the introduction of the wasp from that point should be accomplished without difficulty.

THE WEEPING FIG

There is a handsome fig tree quite similar to, yet quite distinct from, the Chinese banyan which has almost exactly the same geographical range as the latter. To this tree the name *Ficus Benjamina* has been assigned. It so closely resembles some forms of *Ficus retusa* that it is quite generally confused with these and considered as belonging to the same species. In Java it shares with *Ficus retusa* the name Waringin and affords many subjects which are carved into geometrical forms as already described under the Chinese banyan.

Ficus Benjamina may be distinguished from *Ficus retusa* by its slightly longer and more pointed leaves which are placed at greater intervals on the twigs. Its branches are more slender and their gracefully drooping habit has earned for the tree the name Weeping Fig. Like some varieties of the Chinese banyan, the Weeping Fig rarely if ever produces drop-roots, its crown being supported by a single trunk. There are two recognized varieties of the Weeping Fig which differ from each other only in the size of the fruit which they produce. The type of the species bears fruit only $\frac{1}{3}$ inch in diameter while the variety *comosa* bears fruit $\frac{3}{4}$ inch in diameter.

So far as we have been able to ascertain there are no specimens of *Ficus Benjamina* proper in Honolulu but there are four or five specimens of the variety *comosa*. Two of these are growing in Mrs. Foster's garden on Nuuanu, one in Mr. Albert Horner's yard on upper Nuuanu and one in the Spreckels tract in Punahou.

Ficus Benjamina var. *comosa* is a very fine forest tree and a choice ornamental. It could certainly be used to good advantage in the reforestation of our watersheds and should prove especially valuable in the middle and lower zones of our forests. The introduction of the wasp attached to the Weeping Fig has been approved by the Board of Commissioners of Agriculture and Forestry and it is hoped that a serious attempt may be made soon to establish it in our trees.

THE INDIARUBBER TREE

The well known Indiarubber tree of horticulture, *Ficus elastica*, was at one time held to be a rubber-producer of great promise. It is by far the most important of the indigenous rubber trees of India and in the early days of the rubber industry was planted on a large scale both in India and Java. When the Para rubber tree, *Hevea Brasiliensis*, was introduced into the orient, however, it quickly demonstrated its superiority over *Ficus elastica* as a rubber producer and soon replaced the latter in all commercial plantings.

The Indiarubber tree is one of the most stately species of the genus *Ficus*. It is a rapid grower and attains gigantic size. Its main branches tend to approach the vertical rather than the horizontal direction, giving it an attitude of loftiness that is pleasing to look at and agreeable to the plants of lesser stature which must be associated with it in the forest.

There are many fine specimens of the Indiarubber tree to be found in Honolulu. Probably the largest tree now standing is in the grounds of the Queen Emma home on upper Nuuanu Avenue. Other trees of a goodly size may be seen in Washington Place, in Nuuanu Cemetery, and in the grounds of Lunalilo Home. The trunk of a huge tree at Koloa, Kauai, is the subject illustrated on the front cover of this number of the *Record*. The magnificent specimen in front of the Hilo hotel is known and admired by all who have occasion to stop there. Fourteen Indiarubber trees are standing in the grounds about the manager's house at Kukuihaele. The one shown in the photograph reproduced on the opposite page measured 110 feet over all in 1920. It is about thirty-five years old. There is a robust tree of *Ficus elastica* growing at about 2,500 feet elevation alongside of Mud Lane above Kukuihaele.

In its native land many wild specimens of the Indiarubber tree may be found which are over 200 feet tall and have a crown of 200 feet or more in diameter. The species is an inhabitant of the heavy forests and is most abundant in Assam and Upper Burma. It ascends to an altitude of 5,000 feet in the outer Himalayas.

Of the several species of *Ficus* which have already reached Hawaii from India, we are inclined to consider the Indiarubber tree the most desirable for forestry purposes. Attaining great height as it does it would give to our forest the vertical depth which is so essential and at the same time form a congenial



Fig. 11. *Ficus elastica*. This Indiarubber tree in the arboretum at Kukuihaele measured 110 feet over all in 1920. The tree to the left in the background is a banyan, *Ficus Bengalensis*.

associate for trees and shrubs of lesser stature. In this respect it ranks with the Moreton Bay fig and deserves equal attention. Unfortunately the wasp associated with *Ficus elastica* cannot be obtained at any point this side of India and the time required to travel through the intervening space is a serious obstacle to its successful introduction into Hawaii. The desired result might be accomplished by transporting the fruits in a refrigerator, and the insects would surely come through on a small fruiting tree growing in a tub.

THE PEEPUL OR BO TREE.

The Bodhidruma* at Budh Gaya under which Sramana Gautama meditated and, receiving enlightenment, became Buddha, was named, some 2300 years later, *Ficus religiosa* by Linnaeus. Trees of this species have ever been held most sacred by the Buddhists, while the Hindus have strong religious scruples against injuring them in any way. Seedlings have always been allowed to grow and flourish wherever they chanced to start, and so the tree is often found in inappropriate situations. This tree is probably best known by the Hindi name Pipal or Peepul, but in Ceylon it is more commonly called the Bo tree.



Fig. 12. *Ficus religiosa*. One of the Peepul trees that may be seen in the Moanalua gardens.

It is claimed that the Bo tree in the ruins of Anuradhapura, near Kandy in Ceylon, is the oldest tree in the world. We are told that this tree has grown from a branch of the very tree under which Buddha sat, the branch having been planted during the year 288 B. C. As a matter of fact, it is but a young tree when its age is compared with that of some of the giant redwoods of California.

* Bodhidruma = Tree of Intelligence.

Ficus religiosa is indigenous to the sub-Himalayan tract of northern India, but it has been extensively planted in all parts of the Orient for over twenty centuries and now is to be found running wild throughout India, Burma, Siam and the Malay peninsula. It makes a good avenue tree and has been planted near temples, wells and other spots subject to adoration. It grows into a large tree of upright habit, is very resistant to drought and survives light frosts. It ascends to 5,000 feet elevation in the outer Himalayas.

The peepul tree is easily recognized among figs by its very striking and peculiar leaves, which are large, heart-shaped and terminated by a slender acumen or tail one to three inches long. The petioles of the leaves are long, slender and very flexible, so the leaves oscillate freely with the slightest breeze. Fruits of the peepul are about a half inch in diameter, and dark purple when ripe.

Ficus religiosa is among the fig trees already approved for use in our forestry work. There are many fine trees growing in Honolulu, the largest specimen being that in the grounds of St. Louis College. Three splendid trees are conspicuous in the Moanalua gardens and one old specimen occurs in Mrs. Foster's garden.

We have grown many young peepul trees from seed and planted them out in the forest. We find it inadvisable to use them above 2,000 feet elevation on Hawaii, however, because they are so severely attacked by the Olinda beetle, which keeps them stripped of foliage.

RUMPHIUS' FIG.

This tree, named *Ficus Rumphii*, after the famous Dutch botanist, Rumphius, is a close relative of the peepul and is in fact so very similar to it that it is often confused with the peepul even by the native residents of India. Its leaves have much the same shape, texture and venation as those of the peepul, but their blades are truncate instead of cordate at the base and they do not end in nearly so long an acumen.

As far as we have been able to determine, there is only one tree of *Ficus Rumphii* in these Islands, and that is growing in Mrs. Foster's garden on Nuuanu avenue. We have reared numerous young trees from seed obtained from India and Siam, and have also grown a few from cuttings taken from the tree in Mrs. Foster's garden.

Rumphius' fig is so similar to the peepul in habit that it probably will not grow under conditions which are unsuited to the peepul, and as the latter is the superior tree, we should strive to propagate it in preference to Rumphius' fig.

THE ROUGH-LEAVED FIG.

Ficus hispida is peculiar among the figs in that its leaves are borne opposite instead of alternate on the twigs. Its fruits are also borne in a peculiar manner, being formed on special short leafless shoots which spring in clusters from the main trunk and larger branches. It is not a large growing tree, but is extremely virile and spreads of itself quite rapidly. It also has a peculiar habit of sending up from its roots new shoots which eventually become new trees. While the

banyan walks over the landscape, the rough-leaved fig crawls under it, but it captures new territory for itself quite as effectually as does the banyan.

Ficus hispida is not a large tree; in fact, it is usually described as a small or medium sized tree. It is an extremely vigorous and aggressive tree, spreading itself quite rapidly by root-suckers and by seed when the proper wasp is associated with it. It is indigenous over a very large area, its range extending from the Himalayas of India and Southern China in the north to the northern part of Australia in the south. It is very common on the Island of Hong Kong.

We know of only one tree of *Ficus hispida* in Honolulu, that being in Mrs. Foster's garden. From cuttings taken from this specimen we have started many new trees and some of those planted in the Manoa arboretum have made exceedingly rapid growth. We are now growing many thousand seedlings of this species from seed obtained in Australia by Mr. Pemberton. These trees will be available for distribution next winter.

FICUS INFECTORIA.

This is a tall growing, wide spreading tree of stately character. It is deciduous, remaining leafless for a short period each year. It is a common component of natural forests over a very wide range, extending from China throughout India, Ceylon and Malaya. It ascends to 5,000 feet elevation in the Himalayas. It is frequently found on steep, barren slopes anchored in the crevices of rocks. It produces figs in abundance when properly placed, but these are quite small, being only one-fourth to one-third of an inch in diameter.

Ficus infectoria is a rapidly growing tree and should make a very efficient member of the plant societies which we wish to build on our watersheds. Up to the present time we have found but one tree of this species in Honolulu, and that is a very large specimen located in Mrs. Foster's garden. Cuttings from this tree strike readily and we now have several fine young trees developing in the Manoa arboretum.

OTHER ORIENTAL FIG TREES.

The genus *Ficus* contains some 700 species, over four-fifths of which are native to the Indo-Malayan region.

In the foregoing paragraphs we have enumerated and described only such species as are already represented in Hawaii by mature specimens and which we know would prove to be desirable trees in the new forests which we wish to create on our watersheds. There are a few other Oriental figs already represented in Hawaii by fruiting specimens of moderate size, but we have not yet been able to identify the species or fully determine their forestry value. None of them appear to be as desirable trees for our forests as the Indiarubber, the Chinese banyan or the peepul tree.

In a recent number of the "Record," F. X. Williams described the more striking fig trees that are to be found in the native forests in the Philippines. Many of these develop into magnificent trees in their natural haunts, and if they

will do as well in Hawaii they will prove most valuable additions to our new flora. From seed which Mr. Williams secured, we are now growing large numbers of seedlings of some fifteen species of Philippine figs. These will be planted out in our forests on various parts of these Islands and if they develop into serviceable forest trees we may eventually introduce the wasps associated with them and thus convert them into self propagating components of our new forests. We are likewise growing seedlings of some ten fig trees of exceptional promise from seed obtained from Java, India, Burma and Siam. It will, of course, be several years before we can accurately judge the forest value of these trees under Hawaiian conditions. The only way we can obtain the desired information is to plant out the trees and await results. This of course applies only to species which have not yet been tried out under Hawaiian conditions. Those described in detail above are already represented by one or more thrifty specimens and have demonstrated their ability to grow and thrive under local conditions, and we may plant them out on our watersheds with full assurance that they will do all that we expect of them.

Earthworms and Their Culture in Relation to Agriculture.

By F. Muir.

One of the most fascinating works of Charles Darwin is "Vegetable Mould and Earthworms." Like many of his works it is written so clearly and simply that no technical knowledge is required to understand and appreciate the evidence brought together and the conclusions to be derived from it.

To anyone considering the matter for the first time without any previous information on the subject, it appears incredible that such soft, comparatively small creatures as earthworms could play any important part in nature. Yet it has been demonstrated that they are responsible for the entire or greater portion of the vegetable mould that covers a large portion of the surface of the land, and which plays such an important part in the lives of men on account of its value for agriculture.

Without agriculture, man is a semi-wild animal living by hunting or roaming about with herds of cattle. So far as worms have prepared large areas of the earth for agriculture, or for good pasture lands, so far have worms contributed to the civilization of mankind.

The long, cylindrical and segmented appearance of earthworms is familiar to almost everyone. The body wall is formed of three layers: an outer epidermis, under this a layer of circular muscle-fibres, and beneath this a layer of longitudinal muscles. Arising from the epidermis are a number of hairs or chaetae which evidently serve as passive organs of locomotion. By the alternate contraction and expansion of the longitudinal and circular muscles the worm can make itself thick and short or long and thin, and by the aid of these passive organs of locomotion a

hold can be gotten on the surface of the soil or in the burrow. If we cut a worm longitudinally and open the body wall, the digestive tube is seen to be running from end to end perfectly straight. At the anterior end the mouth forms a sucker; this leads into the buccal cavity; then into a larger cavity, the pharynx; then into a narrower oesophagus which is long, muscular, with thick walls, and enlarges into a crop; and then into a gizzard. This gizzard has very thick muscular walls and a stout lining of chitin. The remainder of the digestive tube is the wider intestine which is large and opens at the posterior end of the worm. On the oesophagus are three pair of calciferous glands which are remarkable, for nothing like them is known in other animals. It is suggested that their secretions neutralize the humus acids of the food. The gizzard crushes and grinds the food and small bits of stones are generally found in it.

Worms live in the soil in burrows which they make by either forcing or eating their way through the loose soil. With their head at the bottom of the burrow they excavate the soil with their mouth and swallow it. This is then cast out at the mouth of the burrow as "casts." Worms generally live near the surface. In dry or cold weather they penetrate to considerable depths and are found even to sixty-six inches below the surface. Their burrows are lined with fine dark soil voided by the worm, the entrance often being lined with bits of leaves and closed with small stones and other objects. The food consists of vegetable matter which they get by swallowing bits of leaves etc., or by swallowing soil containing vegetable matter. Darwin showed that they exercise considerable intelligence in selecting their food and in dragging it into their burrows.

This action of burrowing into the soil and voiding the excavated soil onto the surface causes the ground to be perforated with many burrows. These, in the course of time, collapse and the soil cast up settles down. As only fine soil is swallowed, this means that in the course of years the top surface consists entirely of soil sifted through the digestive tubes of worms, ground in their gizzard, mixed with remains of leaves and other vegetable matter and saturated with their secretions, and its whole chemical and mechanical nature considerably changed.

When we consider a single worm, the above all seems very impractical even if theoretically true. It is only when we realize the wide distribution of worms and their numbers that we can realize the great part they play in nature's economy.

In Europe it was estimated by Hansen that in a kitchen garden there are 53,767 living worms in an acre, there being nine burrows in two square feet. Worms would not be so numerous in poorer soils, but even if we take half this number as an average it gives astonishing results.

From a series of observations in different localities it is calculated that twenty ounces of soil are ejected by each worm annually. This would give fifteen tons as the weight of the castings annually thrown up on an acre of land.

The work of worms, turning up the soil and burying objects, has been demonstrated by actual experiments. Objects, such as chalk, coal, etc., scattered over the surface of pasture land soon disappears, and if dug up after a number of years are found to be some distance below the surface, all in the same plane, thus showing that the whole surface has sunk at a uniform rate. Five experiments showed the following results in different soils after ten years: 2.2 inches, 1.9

inches, 2.1 inches, 2.2 inches, 0.83 inches. This would give an average of nearly .2 inch a year.

A considerable portion of Darwin's work is to show that large objects, such as stones, buildings and pavements have been buried to considerable depths by the action of worms. He also points out the great part they play in the geology of the land.

The following passages from Darwin's work give his conclusion as to the value of worms as agriculturists:

Worms have played a more important part in the history of the world than most persons would at first suppose. In almost all humid countries they are extraordinarily numerous, and for their size possess great muscular power. In many parts of England a weight of more than ten tons (10,516 kilogrammes) of dry earth annually passes through their bodies and is brought to the surface on each acre of land; so that the whole superficial bed of vegetable mould passes through their bodies in the course of every few years. From the collapsing of the old burrows the mould is in constant though slow movement, and the particles composing it are thus rubbed together. By these means fresh surfaces are continually exposed to the action of the carbonic acid in the soil, and of the humus-acids which appear to be still more efficient in the decomposition of rocks. The generation of the humus-acids is probably hastened during the digestion of the many half-decayed leaves which worms consume. Thus the particles of earth, forming the superficial mould, are subjected to conditions eminently favorable for their decomposition and disintegration. Moreover, the particles of the softer rocks suffer some amount of mechanical trituration in the muscular gizzards of worms, in which small stones serve as mill-stones. . . .

Worms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds. They periodically expose the mould to the air, and sift it so that no stones larger than the particles which they can swallow are left in it. They mingle the whole intimately together, like a gardener who prepares fine soil for his choicest plants. In this state it is well fitted to retain moisture and to absorb all soluble substances, as well as for the process of nitrification. The bones of dead animals, the harder parts of insects, the shells of land-molluscs, leaves, twigs, etc., before long are all buried beneath the accumulated castings of worms, and are thus brought in a more or less decayed state within reach of the roots of plants. Worms likewise drag an infinite number of dead leaves and other parts of plants into their burrows, partly for the sake of plugging them up and partly as food.

The leaves which are dragged into the burrows as food, after being torn into the finest shreds, partially digested, and saturated with the intestinal and urinary secretions, are commingled with much earth. This earth forms the dark colored, rich humus which almost everywhere covers the surface of the land with a fairly well-defined layer or mantle.

It is believed by some persons that worm burrows, which often penetrate the ground almost perpendicularly to a depth of five or six feet, materially aid in its drainage; notwithstanding that the viscid castings piled over the mouths of the burrows prevent or check the rain-water directly entering them. They allow the air to penetrate deeply into the ground. They also greatly facilitate the downward passage of roots of moderate size; and these will be nourished by the humus with which the burrows are lined. Many seeds owe their germination to having been covered by castings; and others buried to a considerable depth beneath accumulated castings lie dormant, until at some future time they are accidentally uncovered and germinate. . . .

When we behold a wide, turf-covered expanse, we should remember that its smoothness, on which so much of its beauty depends, is mainly due to all the inequalities having been slowly levelled by worms. It is a marvellous reflection that the whole of the superficial mould over any such expanse has passed, and will again pass, every few years through the bodies of worms. The plough is one of the most ancient and most valuable of man's

inventions; but long before he existed the land was in fact regularly ploughed, and still continues to be thus ploughed by earthworms. It may be doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly organized creatures. Some other animals, however, still more lowly organized, namely corals, have done far more conspicuous work in having constructed innumerable reefs and islands in the great oceans; but these are almost confined to the tropical zones.

Turning from earthworms to a closely related family, Enchytraeidae, we find that recent investigations indicate that these little creatures, hitherto considered as of no importance to agriculture, possibly play an important role. These are small or minute worms, mostly considerably less than an inch in length, that live in soil or water and are common in soils in most parts of the world. G. Jegen, a biologist in Europe, has been studying the habits of some of these worms and finds that they live upon nematodes, such as the destructive *Tylenchus devastatrix* and *Aphelenchus ormeroides*. When we consider how harmful nematodes are to crops in many parts of the world the value of these little worms becomes apparent.

Does all this information about "worms" have any bearing upon agriculture in Hawaii?

If we turn to the "Fauna Hawaiiensis," the store house of information of the land animals of our islands, we find that Dr. Perkins collected twelve species of earthworms, mostly in out of the way places in the mountains where native species were most likely to be found. Of these twelve only one is doubtfully native, all the others being found in various parts of the world, and were evidently introduced by man comparatively recently. It is doubtful if earthworms existed in the islands before the advent of the white men. Most of our worms have evidently been brought from Asia as several of the species found here have been taken in Hongkong.

A characteristic of the soils of these islands is a comparative absence of the layer of vegetable mould found in many parts of the world, even in our moister districts. We have deep, fine soils in some parts, but these are comparatively free from humus and in our damp forests where conditions are ideal for the accumulation of vegetable mould we do not find that 18 to 24 inches of fine, well shifted mould rich in vegetable matter, in anything like the same proportion as we do in many other parts of the world. Is it not possible that this is due to the absence of earthworms in these islands in long past ages?

Even now that we have accidentally acquired a dozen species or so have we those that are best suited for our soils and which are capable of doing the greatest good? In South Africa there are worms that throw up casts of 25 cubic inches or more. In our meadow lands and on our lawns our grass is very poor and thin. May it not be due to the comparative scarcity of worms throwing up the soil through which the grass grows so that in a few years' time the turf is thick? These are all questions into which it is well worth inquiring.

Of the Enchytraeidae we have no single example in the island so far as is known at present. Would it not be well to inquire further into the habits of these worms in Europe and elsewhere where Nematodes are not reported as being so very injurious, and where agriculture has been carried on for many hundreds of years?

The more we know of nature, the more we find that the destiny of the human race is bound up more with the smaller creatures of the universe than with the greater.

Mosaic Disease on a New Grass Host.

By L. O. KUNKEL.

It has recently been observed that the wild grass *Chaetochloa verticillata*, which is a rather common weed in cane fields and along roads and watercourses, is subject to mosaic. The disease often attacks this host severely, causing a



Chaetochloa verticillata.

marked discoloration of the leaves and a stunting of the whole plant. It closely resembles the mosaic on sugar cane and may be the same disease. This possibility brings the grass under suspicion as a means of spreading mosaic to cane. Experiments to determine this point are now under way. In the meantime it should be looked on as a dangerous weed.

Chaetochloa verticillata, which is one of the bristly, foxtail grasses, is an annual. It grows in dense tufts and reaches a height of from one to two feet. Seed is produced in cylindrical spike-like panicles. The panicles, especially when ripe, readily become attached to clothing by means of downwardly

barbed bristles which surround the spikelets. The accompanying illustration, which shows a portion of a mature plant, may be of aid in identifying the grass.

Experiments at Oahu Sugar Company.

By J. A. VERRET.

GENERAL.

These experiments are on the Oahu Sugar Company plantation in field 45 B at an elevation of about 550 feet.

About half the area of this experiment was in Lahaina cane and was suffering severely from Root-rot or so-called Lahaina disease. It was therefore decided to harvest this field early and plow it up in order to plant some other variety of cane. The 1920 crop was harvested in November, 1920, and the last one in February, 1922, the cane being fifteen months old at the time.

The cane juices were taken from carload lots at the mill.

This is the third crop harvested from these experiments; the first crop, in 1918, was planted on virgin land.

The results of the 1920 and 1922 crops from this area show in an interesting way the advantage of reporting sugar yields on the basis of "sugar per acre per month" rather than "sugar per acre" only.

The yield in 1920 from a series of plots receiving uniform treatment amounted to 13 tons of sugar per acre. The yield from the same plots in 1922 was $5\frac{1}{4}$ tons of sugar. At first sight this appears to be a tremendous difference. On closer study of the records, however, we find this difference to be more apparent than real.

The 1920 crop occupied the land from March 1918 to November 1920, a period of 32 months. The 1922 crop occupied the land from November 1920 to February 1922, a period of 15 months.

The amount of sugar actually produced per acre per month for these two crops figures out as follows:

1920 crop=0.413 ton p. a. p. m.

1922 crop=0.347 " " " " "

This is a difference of only 16%.

The results obtained in this field are briefly summarized as follows:

1st. Varieties: Lahaina, Striped Mexican, H 146, H 109, Badila, Yellow Caledonia, H 333, H 227 and D 1135 were compared. Lahaina and H 146 failed on account of Root-rot. H 333 was killed by Eye-spot. H 227 and Yellow Caledonia did not do well. H 109 and D 1135 gave the best yields. H 456, Badila, and Striped Mexican did fairly well.

2nd. The economic response to nitrogen fertilization varied from 150 to 225 pounds per acre, the average being 200 pounds. This would be supplied by say 900 pounds of high grade containing 11% nitrogen and 650 pounds of nitrate of soda.

3rd. Potash was of no value in increasing yields.

4th. The response to phosphoric acid fertilization was large. From 90 to 120 pounds per acre of P_2O_5 (550 to 700 pounds of acid phosphate) can be used to advantage.

OAHU SUGAR CO. EXPTS. 3,4,5,6,&8, 1922 CROP FIELD 45.



EXPERIMENT NO. 3—AMOUNTS OF NITROGEN.

All plots received phosphoric acid and potash. The amounts of nitrogen used varied from nothing to 375 pounds per acre. The cane was D 1135.

The tons of sugar obtained for three crops are as follows:

Treatment	Yield per Acre		
	1918 21 Months	1920 32 Months	1922 15 Months
No nitrogen	5.93	9.00	3.46
75 pounds nitrogen.....	6.73	10.20	4.60
150 " "	7.30	11.38	5.14
225 " "	7.71	10.95	5.50
300 " "	7.41	10.94	5.31
375 " "	7.69	10.81	5.13

The effect of varying amounts of fertilizer on the quality of the juices is shown below:

QUALITY RATION OF JUICES FROM EXPERIMENT NO. 3

Treatment	1918 Crop	1920 Crop	1922 Crop	Average
No nitrogen.....	9.38	7.11	7.90	8.13
75 pounds nitrogen.....	9.69	7.32	7.87	8.29
150 " "	9.91	7.96	8.31	8.73
225 " "	9.94	8.53	8.51	8.99
300 " "	10.61	8.47	8.40	9.16
375 " "	10.93	8.64	9.04	9.54

The 1918 crop was harvested in March, the 1920 in November, and the 1922 in February. The last fertilization to the 1918 crop was applied in July 1917, for the 1920 and 1922 crops, it was applied in May. That was in all cases too late for best results, especially when the cane is harvested early.

The juices show a continued lowering in quality as the amounts of nitrogen are increased. The figures with which we are mostly concerned are those showing the difference between 150 and 225 pounds of nitrogen per acre. When the nitrogen is increased from 150 to 225 pounds, the quality ratio is raised 0.26 ton of cane, amounting to about 3%. Getting the cane to the mill one day sooner after burning would just about make up for this.

But it must be distinctly recognized that increasing the nitrogen fertilizer has a tendency to lower the quality of the juices, all other things being equal. Up to a certain point, this is more than made up by increased cane tonnage. In order to avoid this as much as possible the second season fertilization should be finished as early as practical. The results of our fertilizer experiments lead us to believe heavy fertilization finished in March will give as good juices as lighter applications in June or July.

Details of Experiment.

Amount of nitrogen to apply—0, 75, 150, 225, 300, and 375 lbs. nitrogen per acre.

Object:

To determine the most profitable amount of nitrogen to apply to 2nd ratoons, long. Note: In the plant and first ratoons preceding the present crop, the three plant foods, nitrogen, phosphoric acid, and potash, were applied in variable quantities. For this crop, phosphoric acid and potash are applied uniformly to all plots, nitrogen being the only variable.

Location:

Field 45, sections 1, 2, 3, and 4 of the experimental area in this field, Kunia side of the straight ditch.

Crop:

Lahaina and D 1135, 2nd ratoons, long.

Layout:

No. of plots: 94.

Size of plots: 1/10 acre each (79.2' x 55') consisting of 20 single rows (or 10 double rows). Each plot two watercourses in width; each single row 1/200 acre. These areas include watercourses. For level and straight ditches add 2.5%.

Plan:

Fertilization—pounds nitrogen per acre:

Plots	No. of Plots	As M.F. Jan.-Feb. 1921	As N.S. May-June 1921	Total Lbs. Nit.
A	15	0	0	0
B	16	37.5	37.5	75
C	16	75.0	75.0	150
D	17	112.5	112.5	225
E	16	150.0	150.0	300
F	14	187.5	187.5	375
Cane Crop	17.6	75.0	75.0	150

All plots to receive uniform dose of 150 pounds of P_2O_5 as acid phosphate, including that in mixed fertilizer, and 50 pounds K_2O applied in a separate dressing, Jan.-Feb. 1921.

M. F.=mixed fertilizer 11% N. (7% sulf., 3% nitrate, 1% organic.); 9% P_2O_5 (super bonemeal).

N. S.=nitrate of soda 15.5% N.

EXPERIMENT NO. 4—AMOUNTS OF PHOSPHORIC ACID AND POTASH.

In this test all plots received nitrogen at the rate of 200 pounds per acre. The amounts of phosphoric acid and potash were varied. The results obtained from the D 1135 for three crops are given as follows:

1918 CROP—PLANT

Treatment			Yield Per Acre			Gain in Sugar over Plots Getting Nitro- gen Only
N.	P ₂ O ₅	K ₂ O	Cane	Q. R.	Sugar	
200	30	20	59.4	9.68	6.14	+0.68
200	0	0	51.8	9.47	5.46	
200	60	40	60.5	9.71	6.23	+0.78
200	0	0	50.4	9.26	5.45	
200	90	60	64.8	10.51	6.17	+1.40
200	0	0	49.1	10.28	4.77	
200	120	80	65.5	11.02	5.95	+1.37
200	0	0	47.7	10.19	4.68	

1920 CROP—1st RATOONS

Treatment			Yield Per Acre			Gains Over Nitrogen Plots
N.	P ₂ O ₅	K ₂ O	Cane	Q. R.	Sugar	
200	30	20	78.7	7.17	10.98	+1.92
200	0	20	67.6	7.46	9.06	
200	60	40	89.5	7.73	11.57	+2.00
200	0	20	71.0	7.46	9.57	
200	90	60	91.0	7.59	12.22	+2.02
200	0	20	76.0	7.46	10.20	
200	120	80	99.5	7.21	13.79	+4.71
200	0	20	67.8	7.56	9.08	

1922 CROP—2nd RATOONS

Treatment			Yield Per Acre			Gain Due to Phos. Acid
N.	P ₂ O ₅	K ₂ O	Cane	Q. R.	Sugar	
175	0	50	37.8	8.72	4.33	
175	60	50	40.3	8.60	4.69	+0.36
175	90	50	41.5	8.75	4.74	+0.41
175	150	50	44.5	9.33	4.81	+0.48
175	180	50	44.2	9.12	4.84	+0.51

The soil in this field is high in potash. In an adjoining area no gains were obtained from potash. Therefore the gains obtained here are due to the phosphoric acid.

These results indicate that economic gains are obtained in phosphoric acid applications of from 90 to 120 pounds of P₂O₅ per acre. This corresponds to from 550 to say 700 pounds of acid phosphate.

Details of Experiment.

PHOSPHORIC ACID—AMOUNT TO APPLY.

Object:

To determine the most profitable amount of phosphoric acid to apply to these mauka lands. Comparing 60, 90, 120, 150, and 180 pounds per acre.

Location:

Field 45, section 11 of the experimental area.

Crop:

Lahaina, D 1135 and H 109, 2nd ratoons, long.

Layout:

Number of plots: 63.

Size of plots: 1/10 acre each (79.2' x 55') consisting of 20 single rows (or 10 double rows). Each plot is 2 watercourses wide; each single row 1/200 acre. These areas include watercourses. For level and straight ditches add 2.5%.

Plan:

Fertilization—pounds per acre:

Plots	No. Plots	Jan.-Feb. 1921			May-June 1921		Total Lbs. per Acre	
		N	P ₂ O ₅	K ₂ O	N	N	P ₂ O ₅	K ₂ O
A	0	87.5	60	50	87.5	175	60	50
B	8	87.5	90	50	87.5	175	90	50
X	31	87.5	120	50	87.5	175	120	50
C	8	87.5	150	50	87.5	175	150	50
D	8	87.5	180	50	87.5	175	180	50
Crop C	11.3	87.5	120	—	87.5	175	120	..

N and P₂O₅ from mixed fertilizer=11%N (7% Sulph., 3% Nit., 1% Org.);

and 9% P₂O₅ (Super bonemeal)

Nitrate of soda=15.5% N.

Potash from sulphate = 50.0% K₂O.

EXPERIMENT NO. 5—VARIETIES.

In this experiment Lahaina, Striped Mexican, H 109, H 146, H 227, H 333, Badila, Yellow Caledonia and H 456 are compared.

From the results of three crops, one plant and two ratoons, Yellow Caledonia, H 227, H 333, Lahaina and H 146 were found not suited to this locality. Lahaina and H 146 developed Root-rot. Yellow Caledonia and H 227 gave poor yields, while H 333 was killed by Eye-spot. H 109 also suffered from Eye-spot, but in this particular field this was never severe enough to prevent it from giving good yields.

The yields in tons of sugar from the four best varieties are given as follows for the three crops:

TONS SUGAR PER ACRE.

Variety	1918	1920	1922	Average
H 109	8.80	12.80	4.85	8.82
Str. Mex.	8.24	10.45	4.57	7.79
Badila	7.90	9.43	4.95	7.43
H 456	...	10.55	4.10	7.33

D 1135 grown in adjoining areas gave yields approximating those of H 109.

*Details of Experiment.***Object:**

VARIETY TEST.

To compare Lahaina with Striped Mexican, H 109, H 146, H 227, H 456,* Badila and Yellow Caledonia. (Second ratoons, long.)

Location:

Field 45, sections 4, 5, 7, 8, 9, and 10 of the experimental area of this field.

Crop:

Varieties as above, 2nd ratoon long except H 456 which is first ratoon long.

Layout:

No. of plots: 99.

Size of plots: 1/10 acre each (79.2'x 55'), consisting of 20 single rows (or double rows). Each plot is 2 watercourses wide. Each single row is 1/200 acre. These areas include watercourses. For level and straight ditches 2.5% should be added.

Plan:

Fertilization uniform to all plots as follows:

	Jan.-Feb. 1921		May-June 1921	Total Lbs.
	M. F.	Acid Phos.	N. S.	
Nit.	75		75	150
P ₂ O ₅	61	92		153

Experiment originally planned by L. D. Larsen.

Experiment originally laid out by J. S. B. Pratt.

Experiment harvested by Y. Kutsunai.

* For 1920 crop H 456 was substituted for H 333.

M. F.=11% (7% sulf., 3% nit., 1% org.)

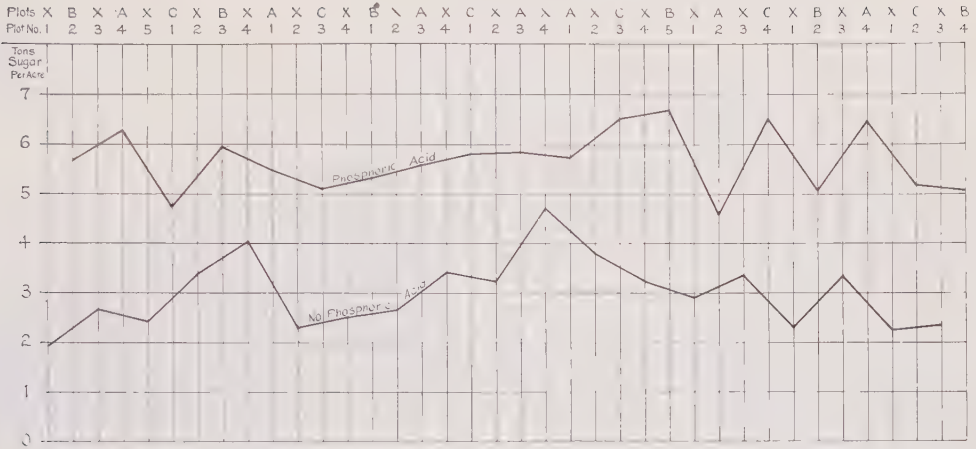
9% P₂O₅

Acid Phosphate=17% P₂O₅

EXPERIMENT NO. 6—PHOSPHORIC ACID.

The main purpose of this experiment was to compare equal amounts of P₂O₅ from acid phosphate and from reverted phosphate.

PHOSPHORIC ACID VS. NO PHOSPHORIC ACID.

Oahu Sugar Co. Exp. 6, 1922 Crop
2nd Ratoons, Long

The results in tons of sugar from three crops were as follows:

Treatment	Tons Sugar per Acre			Average Per Crop
	1918	1920	1922	
90 lbs. P_2O_5 from Acid phos.	8.40	14.29	5.66	9.45
90 lbs. P_2O_5 reverted phos.	8.17	15.46	5.64	9.75

Comparing phosphates with no phosphates we obtained the following results:

Treatment	Tons Sugar Per Acre			Average Per Crop
	1918	1920	1922	
90 lbs. P_2O_5 per acre	8.28	14.87	5.65	9.60
No phosphates	7.07	12.38	3.01	7.47

Details of Experiment.

PHOSPHORIC ACID EXPERIMENT.

1. Reverted phosphate.
2. Super phosphate.
3. No phosphate.

Object:

To determine the value of applying reverted phosphate as against applying acid phosphate or no phosphate.

Note: This is a duplication of the experiment as laid out for the 1918 crop requiring harvesting data from two consecutive crops.

Location:

Field 45, divisions 1 on both sides of the straight ditch which runs through the experimental area.

Crop: H 109, second ratoon, long.

Layout:

No. of plots: 38.

Size of plots: 1/22 acre each (36' x 55') consisting of 10 single rows each 5.5' x 36'. Each plot is one watercourse in width and each single row is 1/220 acre. These areas include watercourses. For level and straight ditches add 2.5%.

Plan:

"A" plots=180 lbs. per acre of phosphoric acid as reverted phosphate applied Jan. 1921—to last for two crops.

"B" plots=90 lbs. per acre of phosphoric acid as reverted phosphate applied Jan. 1921 to each crop.

"C" plots=90 lbs. per acre of phosphoric acid as acid phosphate applied in January to each crop.

"X" plots=No phosphoric acid.

All plots to receive uniform dose of 175 lbs. nitrogen in two equal doses and 50 lbs. potash in one dose.

Nitrogen from nitrate of soda—15.5% N.

Potash from sulfate of potash—50.0% K_2O .

EXPERIMENT NO. 8—POTASH.

We here tested the value of potash applications to a soil high in total potash, 0.80%.

The results show no gains from the use of potash. The yields for the two treatments follow:

Treatment	Yield per Acre		
	Cane	Q. R.	Sugar
Potash	44.2	8.60	5.13
No Potash	45.8	8.68	5.30

*Details of Experiment.***POTASH.****Object:**

To determine the value of potash on the mauka land of Oahu Sugar Co.

Location:

Field 45, in the makai Kipapa corner of the experimental area of this field (Section 12).

Crop:

Lahaina and D 1135 with H 109 crop cane.

All 2nd ratoons long.

Layout:

No. of plots: 21.

Size of plots: 1/10 acre each (55' x 79.2') consisting of 20 single rows (10 double rows).

Each plot two watercourses in width; each single row 1/200 acre. These areas include watercourses. For level and straight ditches add 2.5%.

Plan:

Fertilization—pounds per acre:

Plots	No. Plots	Jan.-Feb. 1921			May-June 1921	Total Lbs. per Acre		
		N	P_2O_5	K_2O	N	N	P_2O_5	K_2O
A & B	11	87.5	120	100	87.5	175	120	100
X	10	87.5	120	0	87.5	175	120	0

Nitrogen in first dose applied as mixed—11% (7% Sulf., 3% Nit., 1% Org.); 9% P_2O_5).

Nitrogen in second dose applied as N. S. 15.5% N.

Phosphoric acid applied as mixed with supplementary dose of acid phosphate.

Experiment planned by R. S. Thurston.

Entomological Work in the Philippines.

September 1920—April 1922.

By FRANCIS X. WILLIAMS.

With the exception of a week's stay in Hongkong, China, the work abroad was confined to the Philippine Islands.

OBJECT OF THE WORK.

This was to secure natural enemies of the wireworms, *Monocrepidius exsul* and *Simodactylus cinnamomeus*, which have caused damage to some of the Hawaiian cane fields; to import the fig-wasp which pollinates the flowers of *Ficus rectusa*, of which several trees grow in Hawaii; and to study and establish such other beneficial insects as opportunity offered. In addition, some effort was made to gather seeds of trees which would aid the reforestation work in Hawaii.

ISLANDS VISITED.

Ten islands of the Philippine group were visited. Some of these were comparatively small and unimportant and my stay there—incident to a longer journey—was brief; the larger islands, especially those more or less given over to the cultivation of sugar cane necessitated a residence of some days or weeks. Proceeding from north to south the following islands were visited: Luzon, Polillo, Mindoro, Romblon, Panay, Cebu, Negros, Mindanao, Jolo and Siasi. Everywhere assistance was gladly extended to me. At the College of Agriculture, Los Baños, Luzon, library, laboratory, and insectary facilities were available as well as the aid of the capable scientific staff of that institution. The same was the case with the Forest School there, and of the Bureaus of Forestry and of Science in Manila. Government Experiment Stations, the Sugar Centrals and Haciendas all made work easier, and to them thanks are also due.

Luzon, the largest of the Philippine group is about ten times the area of the Island of Hawaii. Here most of the investigations were carried on at the College of Agriculture, Los Baños, an excellent place to study entomological or botanical problems. The College, part of the University of the Philippines, lies some forty miles southeast of Manila and is in a sugar cane district. The Calamba Sugar Estate is nearby, and the District of Lipa, only a few miles further. The Del Carmen Sugar Central, in Pampanga north of Manila Bay, was twice visited. In Mindoro, a few days were spent at the Mindoro Sugar Estate Company on the southwest coast. In Panay, the sugar cane about Iloilo and that of Capiz Central to the north were investigated. In Cebu, a trip was made to Bogoto towards its northern end, where considerable sugar cane is grown.

The Island of Negros, which is somewhat larger than that of Hawaii is of rather elongate form and in many places the land extends, as a long slope, up to the central mountain mass, thus affording extensive areas for the growth of cane.

Here, especially in Occidental Negros, modern centrals have almost done away with the operation of the crude muscovado sugar mills which dot the country. This island proved the most promising of any for the investigation of sugar cane insects.

Mindanao, the big island to the south is nearly as large as Luzon, and the richest in the Archipelago. Here the sugar industry is only in its infancy. A little cane was investigated at Zamboanga, its chief seaport and also at Iligan on the north coast. The varieties of sugar cane planted, as regards area, are still prevalingly of the native types introduced years ago. Negros Purple and Cebu Purple are such, and are planted over extensive areas. In many places cane is grown on a small scale and is sold in the native stores, a few sticks at a time, for individual or family consumption. Occasionally one may find a few varieties of rather striking appearance in the market places of the southern islands.

WIREWORM PARASITES.

These were not found. As far as I could ascertain wireworms are not a recognized pest of Philippine agriculture and the majority of sugar men were unacquainted with the appearance of the larva. Nevertheless many species inhabit the Archipelago. As a rule they were found in small numbers in the larval stages. Aside from a quite small species whose larva was once found associated with a little bethylid wasp there was no appearance of parasitism. This small wireworm was abundant locally in July 1921 at Del Carmen Central, and full fed was about 8 mm. long. About Los Baños, a few specimens of wireworm larvae of several kinds were unearthed, both in the field and in the forest. Some of the *Monocrepidius* type were somewhat over two inches long. Experiments with these seemed to show that they were at least preferably carnivorous and readily ate white grubs and other wireworm larvae. Here and there wireworms were dug up. At Silay, Negros Occidental, fallow cane fields yielded a few *Monocrepidius* or related larvae, in September, 1921. At Isabela Central, farther south and on the same island I was told of a wireworm infestation, and investigation showed *Monocrepidius* or an ally in fairly good numbers and more or less associated with a large lamellicorn beetle grub infesting a cane field. Here as elsewhere I found no wasps that appeared likely to parasitize *Monocrepidius* or its slenderer relatives.

Blastophaga WASPS FOR *Ficus retusa*.

Ficus retusa is a strangling fig that grows wild in the Philippines. Along the shores of a large lake at Los Baños it was a small tree or shrub on the cliffs. In the forest on Mount Maquililing it occurred as a larger tree, but was neither as tall nor as handsome as a number of other stranglers there. At Hongkong, however, it presented a very good appearance and made an excellent avenue tree. Several shipments of *F. retusa* figs bearing wasps were made to Hawaii but neither the Philippine lots nor the ones from Hongkong yielded the proper insects. Marcotting was tried as a method of transporting the *Blastophaga* in growing figs, but the plants did not show up well, and were continuously dropping their immature fruits. In connection with the work on *Ficus retusa*, many other species of figs and fig wasps were studied or collected. About fifty species of figs—some

vines, others independent trees or shrubs or stranglers—were observed on Mount Maquilang, Luzon, and seven or eight additional kinds on the more southern islands. As a forest cover figs are useful plants and some of the stranglers grow into self-supporting trees, assume very large dimensions, and are noticeable for their wide crowns and stout stems.

PARASITES ON THE BEAN LYCAENID.

Approximately 3000 eggs of a blue butterfly related to our *Polyommatus boeticus* which damages the flowers and seeds of San Hemp, Cow peas, etc., were shipped here in lots from time to time but without yielding the desired egg parasite. A very small consignment of an Ichneumonid wasp that parasitizes the larva of the Philippine butterfly was brought over and liberated at the Federal Experiment Station, as well as a somewhat larger lot of *Odynerus* wasps, one species of which stores its nest with Lycaenid caterpillars. Blue, bean butterflies are numerous in cultivated areas in the Philippines, but more so here where they have not as many enemies.

APHID ENEMIES.

In the Philippines, aphids are often very abundant on legumes, crucifers, etc., but sooner or later their enemies—ladybeetles, Syrphid flies, wasps, etc.—do much to suppress them. Ladybeetles or Coccinellidae appear to be about their most efficient enemy. No aphid enemies survived shipment from Manila. Woolly aphis (*Oregma*) on cane—native and cultivated—and bamboo were found to be attacked by the larva of a small moth.

CRICKET ENEMIES.

Mole crickets (*Gryllotalpa*) and field crickets (*Gryllus*) are pests of not much importance here. However, their reduction in Hawaii is desirable. Three species of Larridae that prey on these insects were released in Honolulu.

DUNG BEETLES.

These enemies of the hornfly were twice shipped in from Manila. Three species, *Onthophagus* sp, *Onites phartopus* and *Catharsius molossus* were represented, but only a few of the first reached maturity in Honolulu and were liberated. A Philippine Histerid beetle occasional under manure was shown to devour fly maggots.

Tephrosia candida AND *Leucaena glauca*.

The seeds of these legumes, especially of the former, are subject to insect attack and a little time was given to studying the enemies of such seed caterpillars.

NUTGRASS (*Cyperus rotundus*) INSECTS.

This sedge, as elsewhere in the tropics, is considered undesirable in the Philippines. In that country there are several insects which weaken or destroy this pest. Two of these were successfully shipped to Honolulu where they are being

tried out in quarantine on some agricultural plants they might injure. It would be inadvisable to liberate such insects if there was a chance of their becoming noxious here. The two insects under probation are the larva of a small moth, identified by O. H. Swezey as *Bactra* sp., which bores into the stem and to some extent into the tuber itself. The other insect, likewise a borer, is a small weevil whose grub has habits much like the caterpillar. Both pupate in the plant. In the Philippines I do not think that this combined work averages more than five per cent effective.

A species of parasitic wasp and a small Tachinid fly preys on the moth caterpillar. The beetle larva seems to have fewer enemies; it is occasionally killed by an exoparasite, the larva of a Chalcid wasp. What seemed to be the same moth caterpillar was found on nutgrass at Hongkong. A dark green Aphid occurs on the leaves, and the base and roots harbor a rather small mealybug. A small blackish flea beetle (*Chrysomelidae*) is occasionally found on this plant. A fungus (*Puccinea* sp.) is very common on nutgrass which it affects in considerable areas, but does not appear to kill it.

CANE DISEASES AND CANE INSECTS.

While in the sugar cane districts I had opportunity of becoming acquainted with various cane pests. Fiji disease and downy mildew were pointed out to me, and what appeared to be Yellow Stripe disease was very prevalent.

Of cane borers a number of species were noted. In Occidental Negros I took a few specimens of a beetle borer, *Mecistocerus* sp. allied to the beetle borer in Hawaii and working in about the same way in cane stems. Specimens in the H. S. P. A. Experiment Station collections show that this species occurs also in the islands to the south of the Philippines. But the borers which are conspicuous by the effects of their work are the caterpillars of certain moths of which several species were found. The moths represent three families, Pyralidae, Noctuidae and Tortricidae, the first prevailing. Some were found in "Talabib" or wild cane (*Saccharum spontaneum*), a tall grass often very abundant about cane fields and elsewhere and doubtless the original food plant of certain cane-attacking insects. Some of the caterpillars are to be found in both old and young cane, others are more or less confined to juvenile plants, plant cane or ratoon, which they attack quite early. Some of these caterpillars go by the name of "point borer," because the point is attacked and then shows as a central withered roll of leaves with one or more of the free leaves in like condition. The injury often extends well into the seed, the few tender joints of the shoot being more or less girdled, and although other shoots are produced, the growth of the cane is retarded. Point borers were found at widely different seasons and their work was sometimes very conspicuous. A few parasites on cane-boring caterpillars were found; one was a tachinid fly, another a Braconid wasp, while a borer pupa produced a number of small Chalcid like wasps.

The sugar cane aphid was not found plentiful, but a woolly aphid (*Oregma lanigera*) was often abundant, though scarcely harmful, on the underside of the leaves. What appeared to be the same insect occurred likewise on wild sugar cane. The sugar cane mealy bug, *Pseudococcus sacchari* was abundant. At North Negros many of the cane stems were found heavily attacked by a diaspine scale.

Several kinds of leafhoppers occur on cane, but are rarely found doing noticeable damage. *Cyrtorhinus* doubtless, and other enemies keep them in check.

The Migratory Locust, *Pathytilus* sp. sometimes does considerable injury to Philippine crops and migrates in clouds. In Northern Panay, what was apparently a small swarm had alighted among some sugar cane in the foothills some days before my arrival. Only a small area of cane was affected, but at every turn of the trowel one or more egg masses of this locust would be unearthed.

WHITE GRUBS.

These are generally widespread in the cane fields and sometimes cause noticeable injury. A number of species are represented but the ones about which complaints seem to be generally made are of large size and parallel the cane grubs in Queensland, Australia. A large Scoliid wasp was found in affected fields. Termites or white ants often appear secondary but sound cane may also be attacked. More than one species is involved.

In general, however, Philippine cane insects are well regulated by their enemies so that the damage done by them is more often slight, sporadic, or at least not usually of major importance.

FOREST CONDITIONS.

Some time was devoted to the study of forest conditions, with special reference to species of figs and to the collection of seeds for reforestation in Hawaii. Later a student at the College of Agriculture was employed in collecting seeds about Los Baños, and in some species large numbers were obtained. Mount Maquiling is very accessible, has an extensive flora, and at certain seasons of the year seeds of forest trees are abundant on the forest floor. Quantities of these seeds are attacked by caterpillars, weevils, etc., and it is important to gather the seeds when freshly fallen and even when still attached to the trees.

A few trips to other forests and mountains were made. The volcanic cones of Mount Banahao near Los Baños and of Canlaon in Negros were visited. Mount Banahao rises to over 7,000 feet. At 4,000 or 5,000 feet oak trees grow abundantly and three species of conifers, one of yew (*Taxus* sp.), and two *Podocarpus* occur at suitable elevations. At the summit one of the latter species prevails. Mount Canlaon is about 8,000 feet high and its deep and precipitous crater is still a little active, there being a strong smell of sulphur in the vicinity. Here, as on other high mountains, temperate zone conditions prevail, and a species of raspberry (*Rubus* sp.) of fairly palatable nature and bumble bees, absent in the lowlands of the tropics, emphasize this point.

A number of photographs of forest trees and forest scenes were taken for the department of forestry of the Experiment Station.

The Improvement of Pineapples Through Bud Selection.*

By A. D. SHAMEL.

INTRODUCTION.

The term bud selection is here used to mean the selection of superior parent plant material for propagation in those crops which are commonly propagated asexually, or, from vegetative parts. The term bud selection as applied to vegetatively propagated plants, as I interpret it, corresponds to the term seed selection as used in the case of plants propagated from seeds.

The behavior of plants under cultivation depends upon two influences, (1) heredity, and (2) environment. We will discuss the hereditary influences in the case of a few vegetatively propagated crop plants from our point of view. The environmental influences include (1) climate, (2) soil, (3) tillage, (4) plant food or fertilizers, (5) water or irrigation practices, (6) light, and (7) fungus or other diseases, insect enemies and other limiting factors. The effect of environmental influences upon plant behavior will not be dwelt upon here. The relation of hereditary influences to plant production, particularly the variations of vegetatively propagated plants under cultivation and the origin of strains from these variations, will be briefly discussed from the standpoint of the isolation, propagation and cultivation of superior strains through systematic bud selection work.

OBJECT OF BUD SELECTION WORK.

The object of plant improvement through bud selection work from the standpoint of this discussion may be divided into two general phases, (1) the discovery of new varieties, and (2) the amelioration of established varieties. That new varieties did or could originate from bud variations in vegetatively propagated plants has been questioned by a few persons until within recent years. That an impressive number of important new varieties of cultivated plants have arisen from bud selection is now proven by an overwhelming mass of indisputable evidence. Furthermore, some of our most important cultivated varieties, heretofore believed to have originated as a result of seminal or seed variations, are now known to have arisen from bud variations. Notwithstanding the great importance to agriculture of this phase of bud selection work, which I have recently discussed in some detail elsewhere,† this discussion will be largely confined to the economic phases and possibilities of bud selection work for the improvement of existing varieties of established worth and value to agriculture.

THE IMPROVEMENT OF ESTABLISHED VARIETIES.

The use of the term "improvement" in plant breeding has frequently been restricted solely to defining, or, as synonymous with the term, the origination of

* A lecture presented at the Short Course on Pineapple Production, University of Hawaii, 1922.

† Improvement of Plants Through Bud Selection, pub. by the Experiment Station, H. S. P. A., 1921.

new varieties. I will use it here to define the amelioration of established varieties as well as to include the origination of new varieties from bud variations. From my experience in plant improvement work I have concluded that from the commercial point of view the amelioration of valuable established varieties is equally important, if not actually of much greater importance, to the origination of new varieties whether they arise from bud or seed variations.

In order to illustrate my point of view on the subject of the amelioration of cultivated varieties, which are commonly propagated from vegetative parts, I will try to describe very briefly some recent important work of this nature.

At the Utah Agricultural Experiment Station systematic hill selection work with potatoes has been underway since 1911. It was found that in studying the progenies of selected hills some of the progenies showed increased production as compared with the progenies of other hills or in comparison with crops grown from unselected stock. By continuing for several years the selection of the best hills in the best progenies, it has been demonstrated that the yield of the variety can be markedly increased in amount and improved in commercial quality. Therefore the culture of the variety can be made more profitable to the grower through systematic bud selection work.

In a comparative trial during 1921 of selected potato plant material with unselected stock, in Southern California, of the same variety and under similar conditions, the crop from the hills of selected plant material produced an average of 175 sacks per acre, while the crop from the unselected plant material was only an average of 35 sacks per acre. Not only was the crop from the hill-selected plant material much larger than that from the unselected stock, but it was also much more uniformly valuable in size of tubers and other important commercial characteristics.

One of the largest and most successful potato growers in the United States has told me that he has increased the yield of the variety of potatoes which he cultivates more than 100 per cent through systematic hill selection work and has improved the commercial quality of the crops in like measure as a result of ten years of bud selection work.

In apples, the Agricultural Experiment Station located at Ottawa, Canada, has recently reported most interesting and important results of bud selection work. Briefly, propagations were made from three selected parent Wealthy trees. The selection of the parent trees was based upon performance records. One of the parent trees was a consistent and regular high yielder; another was a high yielder, but produced irregular crops, high yields alternating with comparatively low yields; and, the third parent tree produced consistently and regularly low yields. No differences in strain or type characteristics were or have been noticed in these three trees to my knowledge, except that the high and regular yielding parent tree showed the greatest vigor of growth and largest size.

During nine years of performance records of the progenies, originally consisting of twenty-five trees each, of the three parent trees, it has been demonstrated that the progenies have behaved almost identically the same as the parent trees. Certainly, no clearer evidence has ever been offered as to the inheritance of yield

characteristics than has been the case with this Canadian apple bud selection investigation.

In the citrus varieties grown in California my associates and I have just completed thirteen years of study of bud variations and bud selection problems. Various bulletins on this citrus fruit improvement work have been issued from time to time by the U. S. Department of Agriculture at Washington, D. C., which can be secured for study if desired.

Briefly, our investigations have revealed the fact that bud variations are common in the citrus varieties. The intentional, but more often the unintentional, propagation of these variations has led to the development of numerous strains having very different characteristics of tree growth, vegetative and fruit characteristics. Through progeny tests it has been found possible to isolate, by means of systematic bud selection work based upon adequate individual tree performance records, the different strains. In this way it has been possible to eliminate the undesirable and to propagate exclusively the desirable strains. Furthermore, in these strains it has been found possible to secure high yielding progenies from some of the highest yielding trees, and low yielding progenies from some of the low yielding trees, indicating that number or amount of fruits is a characteristic subject to bud variation and responding to bud selection in the same way that color, shape, and other fruit characteristics respond.

In our citrus work the improved production, both as regards the amount and the commercial quality of the orchards in which the trees have been grown from carefully selected buds, as compared with the yield of orchards of the same variety and under similar conditions where the trees were grown from unselected buds, amounts to more than 100 percent so far as our records go. As a result of this condition, the citrus bud selection work has been put on a commercial basis by the California Fruit Growers' Exchange, a cooperative organization of about 11,000 citrus growers, in such a way that all citrus growers and nurserymen can secure buds taken from superior parent trees of the best strains in all of the commercial varieties. This work was established in May, 1917, and up to December, 1921, had sold to nurserymen and fruit growers more than 1,650,000 selected citrus buds at the rate of five cents each. The selected buds sold to nurserymen have been generally used in the propagation of new trees, while those sold to fruit growers have ordinarily been used for top-working undesirable trees in established orchards. The charge for the buds is based upon cost and has made this public service work self-supporting from the beginning. In addition to the number of selected buds mentioned above, used in California citrus orchards, the writer and his associates distributed over 1,000,000 selected buds previous to the establishment of the bud department by the Exchange, and many growers select their own buds from superior performance record trees for top-working or other purposes.

In prunes, my associates and I have made some study of bud variation with trees of the French prune variety in California during the past three years. It has been found that the trees of this variety of deciduous fruits develop very striking bud variations. Strains of this variety, originating as bud variations exist, as in the case of the citrus, and possess very different tree and fruit characteristics.

At least one very striking variation has been found, which, if the progeny tests now under way show it to be inherently stable, will probably double the value of the crop.

In ornamental plants, many of the most commonly used plants are known to have originated from bud sports.

In flowers, many of the most important varieties have come from bud variations and have been systematically improved through bud selection work. By referring to the history of the important rose varieties as given in recent numbers of the American Rose Annual, some idea can be gained as to the importance of bud selection with cultivated flowering plants.

With several associates in the Experiment Station of the Hawaiian Sugar Planters' Association, we are now studying the improvement of sugar cane varieties through bud selection. This work is being carried on by means of progeny tests of selected stools in each of the commercially important varieties. While it is not possible to discuss in detail this work at this time, I do not hesitate to offer the opinion that through bud selection sugar cane varieties can be improved in yield of sugar per acre as much as and perhaps more than has been the case in my experience with other crops.

METHODS OF WORK.

The methods of work in bud selection which are fundamentally important from my point of view include (1) selection of parent plants, (2) progeny tests, and (3) multiplication of valuable progenies.

In the selection of parent plants, it is first necessary to become familiar with the plant characteristics and behavior through systematic performance record studies, to develop standards for a comparative study or judging of plant characteristics, and to study the behavior of a large number of individuals under favorable cultural conditions. My experience leads me to suggest that best results can usually be expected in commercial bud selection work for the improvement of a variety of cultivated plants by securing the best fields under the best of cultural conditions for this work. An exception to this general statement should be noted in the case of efforts to secure resistance to disease, drought or other environmental factors, in which event it seems logical that the best results will be obtained by selecting parent plants for progeny tests from the fields affected by disease, drought or other condition for which resistance is desired.

As large a number of carefully selected parent plants should be used in progeny tests as it is possible to handle intelligently. In the propagation of the selected parent plants as many individuals as possible in each progeny should be grown. The number of individuals in each progeny will depend upon many factors, as, for example, the amount of propagating material available from each of the parent plants, the space available for the progeny trials, and the time and assistance which can be given to the study of the progeny behavior.

The conditions in the progeny fields (1) should be favorable to the best growth and development of the plants, (2) should be as uniform as possible in all respects, and (3) should receive the best care throughout the entire history of the progeny tests. Similar plant material should be used from each parent plant,

as, for example, slips in the case of the pineapple, although it is not important in my opinion as to whether the same number of plant pieces or buds be used in each case, and the plant material should be equally spaced and given comparatively uniform conditions throughout all of the progeny plantings.

The important fact to get in mind in this connection is that the progeny test is a method, the most efficient one with which I am familiar, of testing the stability of the inherent characteristics of the parent plants.

The progeny of each parent plant must be arranged so that it can be identified at any time. This can usually be done by driving in stakes in the plant row so as to separate the progenies. These stakes should be (1) substantial, (2) driven firmly into the soil, and (3) located where they will not be disturbed or lost during cultivation. Other methods of separating the progenies are being tried out, but the stake method, if properly used, will answer the purpose.

When the progeny plants have reached maturity, and during the course of their growth, the progeny field should be frequently studied with the greatest possible care. If some progenies are found which are comparatively uniform and desirable, the best individuals in these best progenies should be selected for progeny tests in an additional progeny field. The remaining plant material from the good plants of the best progenies can be used for commercial planting.

SUGGESTIONS FOR PINEAPPLE PROGENY FIELDS.

I have had but little opportunity for studying the pineapple. It has been my privilege to spend several days in pineapple fields when the plants were either approaching or had reached maturity in the sense that the fruits were nearly or quite ripe. In walking down the rows and observing the fruits I was greatly impressed by differences in size, shape, color, maturity, position, and other characteristics of the fruit. Similar observations as to plant behavior revealed to me wide and frequent variations in the habits of growth, leaf characteristics and size of neighboring plants in the same row. Obviously there was a large amount of variation in the plants and fruits which I observed, but whether these differences were inherent or the result of environmental influences I was unable to determine. I do not know the cause of the variations that I observed in pineapple fields and of those variations that doubtless occur in other fields. My suggestions as to the method for achieving this knowledge will be briefly stated in the following paragraphs.

In the first place we are dealing with one variety, as I understand it, the Smooth Cayenne. In the second place we are studying in the fields plants grown from vegetative plant materials. In some fields the plants may be grown from suckers, in others from slips, in others from crowns, in others from ratoon crops with one or more stages of ratooning. It would seem logical to begin this bud selection work if possible in plant fields and wherever practicable in fields where the plants have been grown exclusively from slips, or from crowns, or from suckers, as the case may be. The idea is to get away, so far as possible, from the effect, if any, of the kind of plant material upon plant development, although I am not certain as to the importance of this factor in the case of the pineapple.

From my experience with other similar work the best fields, that is the best crops, should be selected for beginning this work unless resistance is sought which is a somewhat separate problem.

Standards of perfection, particularly in the case of the fruits, should be developed in order to make intelligent parent plant selections for progeny trials. The canners and others having well defined ideas as to the requirements for desirable fruits should be called upon for help in establishing these standards.

With regard to the fruit characteristics, the standards of perfection might include a consideration of (1) size, (2) weight, (3) shape, (4) canning quality, (5) crown, (6) maturity, (7) color, or other recognizable characteristics. Perhaps wax or wooden models of the ideal fruit which can be carried easily in the field, would be of considerable assistance for comparison with fruits observed in the field.

When fruits are found which are satisfactory the plants bearing them should be observed for several important characteristics, including the following: (1) habit of growth, (2) number of slips, (3) number of suckers, (4) vigor of growth, (5) freedom from disease, and perhaps other important considerations.

In passing it may be noted that even if the fruit is nearly perfect, if there are no slips or suckers, or an insufficient number of either, the plant would be an undesirable one for commercial purposes as a parent plant for propagation.

If satisfactory fruits and plants are discovered, and there seems to be no question but that many such exist in some fields, these plants should be marked as parent plants for progeny trials. A red cloth streamer tied to such plants will serve to identify them for this purpose.

When the slips are ready to be taken from the plants for propagation they can be secured by placing all of the slips from a single plant in a separate bag. Common paper bags may be found suitable for this purpose. The main point is to keep the slips from each selected parent plant separate. Two or three slips from each selected plant is a minimum number, and the more slips available on each plant the more reliable and valuable the progeny test will be, in my opinion.

The best of field and cultural conditions should be provided for planting the progenies. If these conditions cannot be met, the work will, in my opinion, likely prove to be unsatisfactory.

In planting the progenies enough suitable, large, stakes should be provided, one for each progeny, before planting is begun. Drive in a stake at the beginning of the first row. Plant the slips from one parent plant. Drive in a stake. Plant the slips from another parent plant. Continue this arrangement until all of the progenies are planted.

It has been found that in going from one row to another, at the ends of the rows it is usually desirable to finish a row then to cross directly to the next row and plant back, the so-called snake fashion or arrangement of planting. There are several advantages to this plan, including ease in the study of the behavior of the plants in the progenies. With this arrangement one follows a row to the end of the progeny field, crosses to the adjoining row and follows it back, and so on until all of the progenies are seen in order. It will help somewhat to paint

one side of each stake, say white, so that one can always easily follow the rows in the same order in which the progenies were planted.

During the growth of the progenies their behavior should be observed from time to time in order to gain information as to any possible progeny differences in plant growth.

When the fruits borne by the progeny plants approach maturity a most careful and systematic comparison and study should be made of the plants and fruits in each progeny, from the standpoint of uniformly good or bad or variable behavior of the plants in each progeny, and from the viewpoint of the behavior of each progeny as compared with others.

Commercially, the progenies with uniformly good fruits and plants are the ones to be considered of more than ordinary value for propagation.

The uniformly good characteristics of all of the fruits and plants within a progeny indicate to me a condition of inherent stability which is of primary and fundamental importance for the isolation of strains which will produce uniformly good crops.

Extreme variations amongst the fruits or plants in a progeny indicate to me a condition of inherent instability which is undesirable for the commercial production of the maximum number or weight of uniformly good fruits. These progenies, the inherently unstable or undesirable ones from any cause, should not be used for further commercial propagation or planting.

The progeny test will enable the grower to isolate and propagate the superior strains and to eliminate the inferior ones.

QUALIFICATIONS FOR SUCCESSFUL BUD SELECTION WORK.

May I suggest what, in my opinion, are the essential qualifications for persons engaging in this work? It is new work, pioneer effort, and for this reason, if for no other, it calls for somewhat unusual qualifications on the part of those who undertake it. There are no well defined roads to follow, so that whoever takes up this work must, in part at least, make his own road.

I can summarize the qualifications which I have in mind under three general heads, viz: (1) capacity for sustained effort, (2) intimate knowledge of the plant, and (3) ability to observe and draw correct conclusions or judge as to individual plant and progeny behavior.

The capacity for sustained effort is rare, but is absolutely essential for success in this work. Discouraging accidents, puzzling plant behavior, skeptical onlookers, and critics, and many other inevitable incidents and drawbacks will soon eliminate all those who undertake this work except those who have the capacity for sustained effort. This phase also includes a determination to find out the facts and a sympathetic point of view. It further means hard work and lots of it, concentrated effort and good physical and mental conditions.

By the term "intimate knowledge" is meant that knowledge that comes from close association with and love for the plant with which one works. The term "experience" does not cover the meaning intended, although intelligent experience is an essential part of it. One may not have this intimate knowledge in the

beginning, but one must develop it as the work progresses or it is doomed to failure.

The ability to observe and to deduce correctly from observations varies with individuals, their training and environment. It can be cultivated. Pre-conceived notions and prejudice must be eliminated so far as possible. The plants must be judged on their merits and as they stand.

The above statements have been directed towards those who do the actual bud selection work. I may also be permitted to suggest what I consider to be important factors of success in the work on the part of those who own or operate the pineapple plantations.

In the first place I suggest that unless it is firmly believed that this work will be of greater value than its cost, no attempt be made to undertake it. In the second place, unless it is decided to carry it out under favorable conditions, no attempt should be made to start it.

If it is believed to be fundamentally important that selected plant material be secured and that favorable conditions can be given it, I would respectfully recommend, (1) that some one having the essential qualifications for this work or who can develop them be put in charge of it; (2) that the person in charge of this work be encouraged by helpful suggestions, active personal assistance when possible or needed, and be given his entire time to it; (3) that the cooperation of all of the plantation organization be used in this work, (a helpful method of finding superior plants may be the offer of prizes for the best plants found by any of the laborers on the plantation); (4) the provision of adequate time to develop fully the possibilities of this work without interruption so far as this is humanly possible.

When superior progenies are found they should be multiplied as rapidly as possible for plantation use. All of the plant material, possibly excepting that from one or a few plants for further progeny work, can be used for this purpose so far as I am able to judge at this time. It may be possible, through new methods of propagation to multiply the valuable progenies very much more quickly than is ordinarily the case. We have now in process of trial new methods of multiplication of valuable citrus and deciduous fruit progenies which promise to increase enormously our capacity for multiplying rapidly valuable trees.

CONCLUSION.

In conclusion I want to thank you for your kind attention to, and consideration of my presentation of this subject. It has been inadequately done on account of my ignorance of the pineapple plant. My one hope is that I may have stimulated in some one amongst my hearers an interest in the subject which will lead to a constructive effort along this line. I shall be very glad indeed to cooperate so far as I am able in any earnest and determined study of this very important subject.

The Absorption and Interaction of Fertilizer Salts and Hawaiian Soils.

Preliminary Report.

By GUY R. STEWART.

INTRODUCTION.

When fertilizer salts are applied to the soil the farmer is primarily interested in obtaining a profitable increase to the crop he is raising. He hopes that the nitrogen, potash and phosphoric acid that he puts on the land will be directly returned to him in corn, potatoes or maybe tobacco if he happens to be on the mainland of the United States. If he is a plantation man on these islands he looks for his increase in sugar.

It was early found in the study of soil fertility that fertilization was not alone a simple problem of feeding the plant with certain nutrients. The effect of these soluble fertilizers upon the soil itself had to be considered. First and foremost there was the question of the retention of the salts within reach of the feeding roots of the crop. Justus Liebig (4) who was probably the first to consider manufacturing an artificial fertilizer tried to prevent all loss of plant food by fusing his fertilizer into an insoluble silicate. The experiment was an eminent success in locking up the fertilizer nutrients so they would not be leached from the soil, but was equally effective in preventing the plant from obtaining any of the salts. Shortly after J. T. Way (7) made the first contributions to our knowledge of the fixing power of the soil. His investigations and numerous later studies have shown us that ammonia, potash and phosphoric acid are fixed by the soil. The completeness of the fixation depends largely upon the type of soil. Detailed experiments showed that the clay fraction of the soil was the portion which principally fixed fertilizing materials though organic matter also possessed considerable absorptive power for ammonia.

Several investigations have been made upon the fixing power of our Hawaiian soils. W. T. McGeorge (5) at the Federal Station carried out a series of studies upon several typical island soils. He placed 100 grams of each soil in a series of glass tubes and determined the retention of a variety of fertilizing salts when passed through the soil in an aqueous solution. His results showed a very high fixing power for phosphates and a considerable retention of potash and ammonia. He obtained some slight evidence of the fixation of nitrates though these salts are ordinarily considered to be completely washed out of the soil.

C. F. Eckart (2) and S. S. Peck (6) of this Station have reported a series of lysimeter studies. In the first group of experiments reported by Mr. Eckart, tankage, fishscrap, hoofmeal, nitrate of soda, sulfate of ammonia and dried blood were each added to large lysimeter tubs holding 188 pounds of soil, with a depth of 14 inches of soil in the tub. Uniform applications of 16.3 grams of nitrogen in each form were made. This application would correspond to about

575 pounds of nitrogen on an acre basis. The soils were then watered at intervals and the nitric nitrogen leached out in the drainage water was determined. A later series dealt with the effect of various forms and amounts of lime upon the soil.

The efficiency of conversion of these organic forms of nitrogen into nitrates was largely judged by the amount of nitrates recovered in the drainage water. With this shallow depth of soil it was concluded that nitrogen from nitrate of soda was rapidly washed out.

Mr. Peck's experiments were reported in two series, one of which dealt with the effect of various forms of lime upon the formation of nitric nitrogen. The other considered the effect of various fertilizer salts, both alone and in combination, on the formation of nitric nitrogen, in an alkaline makai soil from a district of limited rainfall. The soils in these experiments were treated in cylinders two feet deep and eight inches wide. The fertilizer salts were added at the rate of 100 pounds each of nitrogen, potash and phosphoric acid per acre foot. The principal object of the experiment was to determine the effect of the single salts and combination of salts upon nitrification. Valuable data, however, were obtained upon the fixing power of the soils. All the phosphoric acid was completely fixed and the greater portion of the potash was also retained. There was also an appreciable retention of nitrogen from both sodium nitrate and calcium nitrate as well as from ammonium sulfate.

Beside the question of the retention of the fertilizer salts in the soil there has been a constantly increasing interest developed as to the final effect of soluble materials upon the physical, chemical, and biological condition of the soil. Several definite chemical interchanges take place immediately after a fertilizer is added. The ammonia radical of any ammonium salt is fixed in the soil while a corresponding amount of lime is freed and passes out in the drainage water along with the acid radical with which the ammonia salt was originally combined. The absorption of potash follows the same general scheme. The potash is fixed and the lime is liberated along with the chloride, sulfate or nitrate which was combined with the potash. Soluble phosphates are fixed in the soil by the calcium, iron and aluminum of the surface soil without any determinable liberation of bases.

It will be seen from the above interactions of fertilizers and soils that the direct effect of the fertilizer is to leave an appreciable amount of soluble lime salts to be washed out of the soil. With the continued application of sodium nitrate it has been found at Rothamsted that there is a tendency for the accumulation of alkaline residues in the soil, leading to the eventual formation of some sodium carbonate. This was shown by chemical examinations of the soil and by the very pasty, puddled physical condition of the sodium nitrate plots.

W. P. Kelly (3) has worked extensively in California upon the effect on citrus trees of continuous irrigation with waters of varying quality, as well as the effect of the use of sodium nitrate as a fertilizer. He has found considerable evidence of the harmful effect of salty and alkaline waters, but is not certain that the alkalinity of the soil has been increased by the sodium nitrate of itself.

Here in the Hawaiian Islands we are following a system of continuous heavy fertilization upon the cane land. On the more favorably located plantations it is customary to apply about a thousand pounds of complete fertilizer containing from 60 to 100 pounds of phosphoric acid, 100 to 120 pounds of nitrogen, and 30 to 100 pounds of potash. The second season from 75 to 150 pounds of nitrogen are applied; usually in the form of nitrate of soda. There is no present superficial evidence that this system of fertilization is producing any harmful results. In fact the writer believes that it is, on the whole, a very desirable system for the plantation to follow. It becomes important, however, for us to try to find how efficiently these nitrogen dressings, such as nitrate of soda, are retained by the soil. It is also desirable for us to know whether there is a tendency for nitrate of soda and our mixed fertilizers to produce an alkaline condition such as is indicated by the Rothamsted experiments.

RETENTION OF NITROGEN SALTS.

The work of H. P. Agee (1) and others at this Station have shown that the majority of the cane roots are located in the top two feet of soil, but part of the roots in deep soil extend down to a depth of about four feet. The retention of nitrogenous salts in four foot columns of soil was first determined. Galvanized iron cylinders four feet long and eight inches wide with a finely perforated bottom were employed in this portion of the work. The lower half of each cylinder was filled with subsoil and the upper half with surface soil.

Four soils were used:

1. A reddish calcareous soil from the Puuloa section of Honolulu Plantation.
2. A dark red manganiferous soil from the upper fields of Oahu Sugar Company.
3. A dark red soil from the mauka fields of Waialua Agricultural Company.
4. A brown silty clay loam from Waipio substation.

It will be seen that the samples included two soils that were fairly typical of many of the mauka soils on the island of Oahu. One of the makai soils, from Waipio substation, is similar to that occurring in many of the productive lower fields of Ewa and Oahu plantations. The other makai soil from Honolulu plantation was chosen because of its high lime content, to try to determine whether there would be a tendency for the interaction of sodium nitrate with the calcium carbonate of the soil to form sodium carbonate.

The nitrogenous salts employed were ammonium sulfate, sodium nitrate and ammonium nitrate. Each of these was added in chemically equivalent amounts so as to add nitrogen at the rate of 155 pounds of nitrogen to the surface foot, equivalent to an application of 1000 pounds of nitrate of soda per acre.

The salts were applied and a two and one-half inch irrigation with tap water was first made. This water contained a moderate concentration of total salts. The loss of ammonia, nitrates and nitrites in the drainage water was then determined. Following this three more irrigations were given at two week intervals, one with two and one-half inches of water and a third and fourth with five inches.

Under field conditions the plant rapidly absorbs the nitrogenous dressings. The purpose of the experiment here was to find the amount of nitrogen that would be lost in a moderate number of irrigations, before the plant would probably have a chance to absorb all the fertilizer. This would also be comparable to the effect of several moderately heavy rains on unirrigated plantations.

Upon analysis of the solutions that percolated through the soil it was found that there were no appreciable amounts of ammonia or nitrites leached out from either the treated or untreated soils. Small traces were present in all the solutions. The nitrogen was not removed from the soil in significant amounts until it was converted over to nitrates. This is clearly shown by the analytical results in Table I. There was practically no added nitrogen removed from the ammonium sulfate treatments by the first and second irrigations. Then the formation of nitrates began to be appreciable and nitrates were removed by the last two irrigations. The results show that it is comparatively safe to use any of the three forms of nitrogen salts upon the Island soils.

The retention of nitrates will vary with the type of soils, but with soils of average depth we may be reasonably sure that the greater part of a nitrate application either as nitrate of soda or ammonium nitrate will not be washed out by any ordinary rain, or the usual irrigations, before the cane has a chance to absorb it.

TABLE I
LOSS OF NITROGENOUS FERTILIZERS FROM FOUR-FOOT SOIL COLUMNS
Results Expressed in Milligrams of Nitrogen

Number of Irriga- tion	Amt. of Irriga- tion	HONOLULU PLANTATION Red Calcareous Soil				OAHU SUGAR COMPANY Red Mauka Soil			
		Blank	Ammon. Sulfate	Sod. Nitrate	Ammon. Nitr.	Blank	Ammon. Sulfate	Sod. Nitr.	Ammon. Nitr.
1	2.5 in.	38.7	40.2	49.2	51.1	89.7	90.5	92.4	103.0
2	2.5 in.	22.5	25.2	11.1	28.6	41.7	45.2	69.0	51.6
3	5.0 in.	158.3	165.2	160.7	164.2	194.4	210.2	229.0	234.0
4	5.0 in.	713.0	890.0	467.0	868.0	464.0	575.0	583.0	504.0
Total loss		932.5	1,120.6	688.0	1,111.9	789.8	920.9	973.4	892.6
		.....	932.5	932.5	932.5	.....	789.8	789.8	789.8
Net loss .....		.....	188.1	0.0	179.4	.....	131.1	183.6	102.8
Nitrogen added...		.....	563	563.0	563	.....	563	563.0	563
Per cent lost ....		.....	33.4	.....	31.8	.....	23.3	32.6	18.2

Number of Irriga- tion	Amt. of Irriga- tion	WAIALUA AGRICULTURE CO. Red Mauka Soil				WAIPIO SUBSTATION Brown Clay Loam			
		Blank	Ammon. Sulfate	Sod. Nitrate	Ammon. Nitr.	Blank	Ammon. Sulfate	Sod. Nitrate	Ammon. Nitrate
1	2.5 in.	140.0	142.0	173.0	151.0	35.9	36.6	53.0	66.7
2	2.5 in.	63.8	65.2	66.9	67.3	26.7	28.2	40.9	26.9
3	5.0 in.	266.8	301.0	322.7	311.5	124.3	155.0	186.8	175.5
4	5.0 in.	584.0	702.0	691.0	569.0	456.0	523.0	513.0	451.0
Total loss		1,054.6	1,210.2	1,253.6	1,088.8	642.9	742.8	793.7	720.1
		.....	1,054.6	1,054.6	1,054.6	.....	642.9	642.9	642.9
Net loss .....		.....	155.6	199.0	34.2	.....	100.9	150.8	87.2
Nitrogen added..		.....	563.0	563.0	563.0	.....	563	563	563.0
Per cent lost ....		.....	27.6	35.3	6.0	.....	17.9	26.8	15.5

LOCALIZATION OF NITROGENOUS APPLICATIONS.

It is of decided interest to know just where the various nitrogenous salts tend to be held in the soil after a heavy rain or irrigation. We have seen that only a moderate part of any of the three under investigation is actually carried out of the soil. This does not, however, show just where the greater part of the salt will be held. The same applications of each salt, that is to say 563 milligrams of nitrogen, representing a fertilization of 155 pounds per acre, were added to cylinders of the same soils. One five-inch irrigation with tap water was made and the percolate analyzed as before. Less than five per cent. of nitrogen from nitrate of soda or ammonium nitrate was carried out of the soils and none of the nitrogen from the ammonium sulfate.

The soil was now removed from each cylinder in one foot sections and in the ammonium sulfate cylinders the top six inches was also analyzed separately. Samples of each section of soil were now shaken with distilled water; and ammonia, nitrites and nitrates determined in the water extracts. The analysis of these extracts and of those from the soils treated with mixed fertilizers was made by F. Hansson of the Chemistry Department. The analytical results are given in Table II. The results for ammonia nitrogen clearly show that with the high fixing power of the Island soils, it has not been possible to extract more than a portion of the ammonia compounds present. The figures do show, however, that the ammonia of the ammonium sulfate and nitrate was fixed in the top foot of soil. The nitrate of both the nitrate of soda and ammonium nitrate was held in general in largest amounts in the second, third and fourth foot. It was still within the feeding zone of the cane plant and would undoubtedly tend to be carried back towards the first foot by the rise of capillary moisture.

TABLE II

LOCALIZATION OF NITROGENOUS SALTS IN FOUR-FOOT COLUMNS

Soil	Ammonium Sulfate			Sodium Nitrate			Ammonium Nitrate			
	Parts per Million Dry Soil			Parts per Million Dry Soil			Parts per Million Dry Soil			
Honolulu Plantation	Ammonia Nitrogen	Nitrite Nitrogen	Nitrate Nitrogen	Ammonia Nitrogen	Nitrite Nitrogen	Nitrate Nitrogen	Ammonia Nitrogen	Nitrite Nitrogen	Nitrate Nitrogen	
1st 6 in...	12.2	1.02	23.0	}	7.7	0.02	8.1	5.9	0.69	20.7
2nd 6 in..	8.0	0.02	15.0							
2nd foot..	6.2	0.01	46.8							
3rd foot..	4.1	0.01	101.1							
4th foot..	2.2	0.01	35.0	}	1.5	0.02	24.2	9.5	0.04	26.7
Oahu Soil										
1st 6 in...	19.3	0.17	146.5							
2nd 6 in..	4.0	0.01	30.0							
2nd foot..	2.1	0.01	88.0	}	1.5	0.02	95.6	3.9	0.01	143.5
3rd foot..	2.0	0.01	79.3							
4th foot..	1.0	0.01	121.8							
Waialua										
1st 6 in...	20.5	0.03	16.4	}	1.3	0.01	28.4	10.4	0.02	15.6
2nd 6 in..	5.2	0.01	13.6							
2nd foot..	2.2	0.01	48.1							
3rd foot..	2.1	0.01	106.7							
4th foot..	2.1	0.02	170.7	}	4.1	0.02	39.4	2.6	0.05	28.0
Waipio										
1st 6 in...	8.9	0.62	19.5							
2nd 6 in..	3.6	0.09	22.3							
2nd foot..	9.1	0.03	32.0	}	4.2	0.01	46.5	2.7	0.01	52.2
3rd foot..	3.7	0.01	29.9							
4th foot..	3.8	0.01	37.7							
				}	1.2	0.01	50.4	1.8	0.02	47.7
				}	1.0	0.01	33.2	2.8	0.1	43.8

INTERACTION OF SOILS AND NITROGENOUS SALTS.

The next study undertaken was the determination of the solubility effect of the three nitrogenous salts upon the same four soils. The salts were added to half-gallon jars of soil which was at the optimum moisture content. The mixture was allowed to stand about three days to give time for the first effects of solution to take place. Portions of the soil were then extracted with water and analyzed for ammonia, nitrates, nitrites, potash, calcium, magnesium, phosphates and total solids. The results are given in Table III and are compared with a similar analysis of the untreated soil.

The detailed results show a number of interesting facts. The same discrepancy between the ammonia salts added and the amount recovered by extraction in water is clearly evident. There is a fairly close agreement for the nitrates found and known to be present. All the salts show a definite solubility effect upon the soil minerals. It is generally considered that sodium nitrate releases the soil potash when it is applied as a fertilizer. There is no evidence that it has done this with the four soils that have been used. In all cases, the

TABLE III
INTERACTION OF NITROGENOUS SALTS AND SOILS
Results Expressed in Parts per Million Dry Soil

Soil	Treatment	Reaction	Ammonia	Nitrite	Nitrate	Potash	Lime	Magne-	Phos-	Total	Volatile	Non Vol.
		Ph	N	N	N	K ₂ O	CaO	sium	phate	Solids	Solids	Solids
								Mgo	P ₂ O ₅			
Honolulu	..... Blank	8.5	4.4	4.9	13.8	86	149	85	22	1,343	356	987
"	..... Sod. Nitrate	8.5	4.4	4.9	72.6	76	180	92	22	1,706	378	1,329
"	..... Am. Nitrate	8.5	5.8	4.9	46.5	131	153	90	30	1,575	399	1,176
"	..... Am. Sulfate	8.4	8.7	4.9	16.7	113	175	92	27	1,699	515	1,183
Oahu Plant	..... Blank	7.7	4.3	0.05	7.8	49	33	30	1.9	399	200	199
"	..... Sod. Nitrate	8.0	5.7	0.10	67.7	40	52	34	2.0	919	328	591
"	..... Am. Nitrate	8.1	7.8	0.05	41.3	86	50	25	1.9	656	214	442
"	..... Am. Sulfate	7.2	17.1	0.10	7.8	79	62	31	1.8	748	214	534
Waialua	..... Blank	7.9	6.9	0.25	28.9	49	53	32	2.0	647	304	343
"	..... Sod. Nitrate	8.0	7.6	0.20	87.5	35	100	47	1.5	1,180	327	852
"	..... Am. Nitrate	8.1	18.3	0.20	60.9	54	78	40	1.7	982	426	556
"	..... Am. Sulfate	7.4	30.4	0.20	30.4	79	69	39	1.5	936	327	609
Waipio	..... Blank	7.7	9.7	0.15	4.1	62	19	12	2.4	452	144	408
"	..... Sod. Nitrate	8.0	2.7	0.35	63.7	48	29	27	2.5	945	301	644
"	..... Am. Nitrate	8.0	4.8	0.35	34.2	52	26	25	2.3	719	281	438
"	..... Am. Sulfate	7.5	13.7	0.20	4.1	64	36	36	3.2	801	199	602

potash is lower in the sodium nitrate treatment than in the untreated soil. The ammonium nitrate and ammonium sulfate do show this influence on most of the soils. All the salts tend to release calcium and magnesium, so it is evident that all these materials exert a solubility effect on the soil, but it is greatest with the two ammonia salts.

The effect of all these salts has been determined upon the reaction of the soil. An exact electrical method has recently been developed for measuring the reaction of soils and other materials in solution. By reaction in this sense is meant the intensity of acidity or alkalinity instead of the total amount present. Extended investigations have shown that it is this intensity factor which is most important to plants and animals. It is usual to express this intensity of reaction on a numerical scale upon which the neutral point, equivalent to the reaction of pure water, is given as Ph 7.0. Numbers less than 7.0 denote greater acidity, while larger numbers show a more alkaline reaction.

In the column headed "Reaction Ph" it will be seen that the Honolulu Plantation soil has a reaction of Ph 8.5. This soil contains over 5.5% of lime as CaO , and this reaction indicates that the soil is completely saturated with lime. The addition of the sodium nitrate and ammonium nitrate did not effect the reaction, while the ammonium sulfate has had its well known effect of causing the soil to change faintly towards the acid side. With the other soils the ammonium sulfate developed a faint degree of acidity and the other two salts caused a slight change towards alkalinity. The effect of this change of reaction would have to be studied in the presence of crops before one could state that it was likely to be in any way harmful. It is known that the sodium nitrate leaves a residue of the sodium ion, or radical, in the soil, while with the ammonium nitrate both radicals are absorbed so the soil should later return to its former reaction.

INTERACTION OF SOILS AND MIXED FERTILIZERS.

The immediate solubility effect of two mixed fertilizers was next determined. Fertilizer No. 1 was a phosphate and nitrogen mixture similar to that used by several plantations. It contained 10% P_2O_5 and 8% total nitrogen equally divided into 4% ammonia nitrogen and 4% nitrate nitrogen. Fertilizer No. 2 was a complete mixture containing 6% total P_2O_5 , 11% total nitrogen subdivided into ammonia nitrogen 4%, nitrate nitrogen 6%, and organic nitrogen 1%. It also contained 6% K_2O .

These two fertilizers were added to half-gallon jars of soil at the rate of 1000 pounds per acre foot of soil. The determinations of water soluble nutrients and the change in reaction are given in Table IV. It is interesting to note that though fertilizer No. 1 contains no water soluble potash, there has been an increase in this material, owing to the solubility effect of the nitrogen mixture. Both this fertilizer and fertilizer No. 2 show an appreciable effect of solution on the other soil materials as evidenced by the increase in calcium, magnesium, and total solids. Each of the mixtures showed a slight increase in alkaline reaction on most of the soils. It is planned to analyze these mixtures of fertilizer and soil after the lapse of several months.

TABLE IV
INTERACTION OF MIXED FERTILIZERS AND SOILS
Results Expressed in Parts per Million Dry Soil

Soil	Treatment	Reaction Ph	Ammonia N	Nitrite N	Nitrate N	Potash K ₂ O	Lime CaO	Magne- sia MgO	Phos- phate P ₂ O ₅	Total Solids	Volatile Solids	Non Volatile Solids
Honolulu	..... Blank	8.5	4.4	4.9	13.8	86	149	85	22.0	1,343	356	987
"	..... Fert. No. 1	8.6	0.2	0.14	72.6	123	178	129	22.1	1,888	327	1,561
"	..... Fert. No. 2	8.7	0.3	0.30	72.6	121	208	121	20.8	1,851	327	1,524
Oahu Sugar Co.	Blank	7.7	4.3	0.05	7.8	49	33	30	1.9	399	200	199
"	" Fert. No. 1	8.3	14.2	0.25	28.5	92	42	39	2.2	713	143	570
"	" Fert. No. 2	8.7	11.4	0.14	44.2	81	37	40	2.6	784	142	642
Waialua	..... Blank	7.9	6.9	0.25	28.9	49	53	32	2.0	647	304	343
"	..... Fert. No. 1	8.2	30.4	0.19	63.9	72	74	50	3.7	1,066	342	724
"	..... Fert. No. 2	8.6	27.4	0.15	65.4	66	74	39	3.1	913	228	685
Waipio	..... Blank	7.7	2.7	0.15	4.1	62	19	12	2.4	452	144	408
"	..... Fert. No. 1	7.7	0.4	0.13	28.7	53	31	48	2.1	856	240	616
"	..... Fert. No. 2	8.2	0.4	0.26	20.5	56	26	43	2.8	719	205	514

SUMMARY.

1. The retention of ammonium sulfate, sodium nitrate and ammonium nitrate was determined in four-foot soil columns of Hawaiian soils of distinctive types.
2. Ammonium sulfate was perfectly retained until nitrification took place.
3. Four irrigations, two of which were heavy, removed from six per cent to thirty-five per cent of the added nitrogen dressings.
4. The ammonia radical was found to be fixed in the top foot of soil.
5. The nitrates were largely washed down into the second, third and fourth foot of soil by one heavy irrigation of approximately six inches of water.
6. All the nitrogen salts showed some solubility effect on the soil minerals. There was more effect from ammonium nitrate and ammonium sulfate in rendering plant food soluble than there was with sodium nitrate.
7. Sodium nitrate and ammonium nitrate caused a slight increase in the alkaline reaction of most of the soils used. Ammonium sulfate showed the usual slight increase in acidity.
8. Mixed fertilizers added to the soil also caused a slight increase in the alkaline reaction of the soil and some effect of secondary solubility on the soil minerals.
9. It is planned to extend these studies to field soils and cultures with sugar cane before trying to apply them to field practice.

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Recovery of Sugar from Last Mill Juice.

BY W. R. McALLEP

With the increase in the amount of sugar extracted from cane, resulting from the improved mill work of recent years, the question has been brought up frequently: How much of the extra sugar extracted is finally obtained in the form of commercial sugar? The two principle factors involved in answering this question are: Is increased extraction accompanied by an increased deterioration of sugar in the mill, and what is the value of the last extracted juice?

With respect to the first of these factors there is no doubt but that some loss through bacterial action always takes place and that compound maceration increases the length of time juices are exposed to such action. Investigation by H. S. Walker¹ at Pioneer Mill Company, and by the writer at several other factories, has shown that, at least when sound cane is ground, the rate of deterioration is slow enough so that the loss is negligible during the time necessary to complete the milling cycle. Deterioration can and does take place in any material that is allowed to accumulate in the mill, juice strainers, etc., thus taking longer than the normal time to complete the cycle. High extraction does not necessarily increase such losses. Observation has given the writer the impression that more often than not the care necessary to secure the high extraction results in cleaner conditions around the mill than when mediocre results are obtained.

The second factor, the value of the last mill juice, depends on the increase in purity during clarification and on the molasses forming action of the remaining impurities. The purity of the last extracted juice is considerable lower than the purity of the juices extracted at preceding mills and the difference is accentuated with increasing extraction. Doubts have frequently been expressed as to whether the molasses resulting from last mill juice could be reduced to as low a purity as that from the previously extracted juices, and sometimes even whether sugar could actually be made from it at all. These opinions have been based largely on the fact that the proportion of glucose decreases and the proportion of ash increases in the last extracted juices. While there is but little reliable information regarding the molasses forming properties of the different impurities, these opinions are not entirely without foundation for glucose does render it easier to secure lower purity molasses, though undue importance is frequently given this factor. Analysis of available figures for Hawaiian mills, however, does not support these views. Horace Johnson,² quoting figures for extraction and recovery extending over a period of several years, concludes: "These results show that not only the sugar due to increased extraction was recovered, but that the quality of the boiling house work has also shown decided improvements."

¹ Record, Vol. XXIV, page 202.

²Report of Committee on Manufacture of Sugar. H. S. P. A. 1918.

While the figures indicate that the expected amount of sugar has been recovered from the last increment of extraction, so far as the writer is aware, this has never been experimentally demonstrated previous to the work herein described. During the latter part of the season of 1921, the writer, assisted by H. F. Bomonti and W. L. McCleery, at the request and with the cooperation of Kahuku Plantation Company, made a study of the crystallization of sugar from last mill juice resulting from very low purity cane. The last mill juice was clarified, evaporated, boiled to a massecuite and the massecuite dried in experimental apparatus, available through the courtesy of this plantation. The work was done under careful chemical control, the analyses including all determinations that seemed of probable value in interpreting the results.

Preliminary clarification studies were made on a laboratory scale, by Mr. Bomonti. It was found that a satisfactory clarification, resulting in comparatively clear, well settled juices could be obtained. The desirable reaction corresponded closely to that of most juices. This is a point from one-half to three-quarters of the way from the neutral point to litmus to the neutral point of phenolphthalein. In these last mill juices it was at an alkalinity to litmus of approximately .012 (% CaO). As is usually the case, it could be approximated by liming the cold juice to the neutral point to phenolphthalein. The presence or absence of cushcush was found to be a material factor in the possible increase in purity. The last mill juice after passing the mill screens contained from 0.7% to 0.8% of suspended solids. This amounted in these dilute juices to between 20% and 25% of the polarization, a much larger ratio than in mixed juice where it ordinarily is between a minimum of 2% and a maximum of 7%. Passing the juice through 100 mesh screen reduced the suspended solids to between .12% and .16% and caused an apparent increase in purity of about 3.5. As no soluble solids had been removed by this screening the increase in purity was apparent only. In reality the purity as ordinarily determined was too low because of the effect of the suspended matter on the brix determination. Removing the coarser of the suspended matter before the addition of lime resulted in a total increase of apparent purity from 2 to 5 points greater than when the screening was done subsequent to clarification. This preliminary work demonstrated that a much greater increase in purity than anticipated, amounting to from 7 to 10 points over the apparent purity of the last mill juice, could be secured after a preliminary screening and a properly conducted clarification with lime.

Last mill juices were clarified and evaporated to syrup on November 9, 10 and 11. The quality of the cane ground at Kahuku on these days and the extraction and dilution are shown in the following tabulation of figures taken from the Kahuku laboratory records:

TABLE 1.

	Nov. 9	Nov. 10	Nov. 11
Purity First Mill Juice ..	72.40	77.88	78.89
Purity Last Mill Juice ...	58.30	65.60	64.20
Dilution	11.52	8.28	8.26
Extraction	93.75	94.23	94.13

While none of the cane was of particularly good quality it varied considerably. The first mill juice from some of it was above 80 while in extreme cases it was below 60 in purity.

The milling equipment at Kahuku consists of a three roller crusher, a Searby shredder and a nine roller mill 34" x 72". It had been intended to utilize the third mill juice resulting from the poorest cane ground, using from 30% to 35% maceration. The maceration was increased while juice for the first two runs was being taken. The desired point, however, was not very closely approximated, the maceration being 20% during the first and 55% during the second run. One cell of the evaporators was being repaired and the full capacity of the remaining equipment was required to evaporate the amount of juice received from the mill with the 8% to 10% maceration then being carried. The increased maceration during runs 1 and 2 caused delays in the factory operations; it also became evident that the experimental pan used as an evaporater was not of sufficient capacity to produce the minimum amount of syrup required for a massecuite from juices as dilute as two or three brix, during the time available for this experiment. For these reasons the maceration was not changed from the amount regularly carried when withdrawing juice for the remaining four runs. While the greater part of the juice used in this experiment resulted from comparatively low maceration, conditions with respect to purity were as severe as could be desired. The average apparent purity of the juice taken was 49.9. According to the Kahuku laboratory records the corresponding purity of the first mill juice was 67.2.

The juice was clarified in old massecuite cooler cars of 90 gallons capacity, fitted with cocks for drawing off the settled juice. A portable steam coil made of 3/4" pipe was used for heating the juice. This coil was immersed in the car, the contents of which were to be heated. Suspended solids in the last mill juice averaged .66%. The juice was passed through a 100 mesh screen previous to clarification, reducing the suspended solids to .20% and increasing the apparent purity from 49.9 to 53.3. After this screening the suspended solids were 6% of the polarization. The screened juice was limed to a slight alkalinity to phenolphthalein, boiled and allowed to settle. With the exception of run number 4, the results were satisfactory. The clarification was good, the settling rapid and the average alkalinity was close to .012. The alkalinity was higher than was desirable in run number 4. Though the total increase in purity in this run was satisfactory, the increase due to lime was smaller, the settled juice was not clear, and there was a tendency to foam during evaporation.

An experimental pan of about 35 gallons capacity, was used for evaporating and boiling. Vacuum obtained was rather low, seldom exceeding 24". Between 15 and 25 gallons of juice per hour could be evaporated, though above the former rate entrainment became heavy. Between 15% and 30% of the solids taken into the pan during this experiment was lost through entrainment. Clear, settled juices only were evaporated, no attempt being made to save the settlings. The syrup from run number 2 was discarded. Difficulties with the pan caused a considerable delay during this run and a quantity of clarified juice that had cooled off and deteriorated badly was drawn into the pan before the deterioration was discovered. The syrup was evaporated to between 70 and 75 brix. At this density there was no detectable deterioration, though some of it was held for three days before boiling without the use of preservatives. The syrup was not very clean for though the settling, except in run number 4, was good, evaporation of from 90% to 96% resulted in the suspended matter being concentrated to a very small volume. The reaction was distinctly alkaline to litmus. Approximately 20 gallons of syrup were obtained from five runs. Apparent purities for the different runs are given in detail in the following tabulation. First mill juice figures are from the Kahuku laboratory records. Run number 2 is omitted from the averages.

TABLE 2.

Run No.	Variety	Purity First Mill Juice	Last Mill Juice			Clarified Juice	Syrup	Increase in Purity
			Brix	Purity	After Screening			
1	Y. C.	65.6	3.07	44.0	48.5	58.1	57.9	13.9
2	?	55.5	2.47	50.2	57.1	63.8	46.2	— 4.0
3	Y. C.	61.4	8.16	47.2	48.6	54.8	55.2	8.0
4	?	70.1	6.26	49.2	54.9	56.9	58.7	9.5
5	Y. C.	67.6	5.91	47.5	51.8	54.2	55.9	8.4
6	Y. C.	72.9	5.91	59.6	62.5	64.5	65.8	6.2
True average		67.2	6.20	49.9	53.3	57.2	58.6	8.7

It will be noted that screening caused an increase of 3.4 in purity; clarification a further increase of 3.9 and there was an increase of 1.4 during evaporation, making a total increase in apparent purity from the last mill juice to syrup 8.7.

The syrup was boiled to a massecuite on November 12. A good grain was readily obtained by thickening half of the syrup to "string proof" and letting it stand a few hours in the pan. A circulating baffle in the pan prevented starting this graining charge to boiling again, and it was necessary to draw in the whole of the syrup. Most of the original grain melted during this manipulation rendering it necessary to bring in a secondary grain that could not be built up to a desirable size for want of material. The massecuite was boiled slowly for several hours to reduce the mother liquor to as low a purity as possible. Some 10 gallons of massecuite of 96 brix, 58.0 apparent and 60.4 gravity purity were

finally secured. No apparatus being available for crystallization in motion or for controlling the temperature of the massecuite during cooling, the massecuite was allowed to mature in buckets.

On November 25, some two weeks after boiling, a sample of molasses separated from a portion of this massecuite was 34.0 gravity purity. The original grain had grown to 0.4 mm. and the secondary grain to 0.1 mm. False grain, formed in the massecuite subsequent to boiling, was from .03 to .05 mm. in size. Such a grain is suitable enough for exhausting the molasses to a low purity, but is not at all suitable for drying in a centrifugal because of the number of crystals measuring under 0.1 mm. There was no indication that the composition of the syrup had anything to do with the failure to secure a satisfactory grain. On the contrary the difficulties were entirely mechanical. If a larger quantity of syrup and suitable apparatus for crystallization in motion had been available, but little difficulty would have been encountered in producing a massecuite with an entirely satisfactory grain.

The massecuite was dried on December 12, one month after boiling, in a 9" experimental centrifugal. This was operated at two speeds, 2120 and 2575 r. p. m. Centrifugal force at the lower speed approximates that of a 40" centrifugal at 1000 r. p. m. and is equivalent to the better Hawaiian practice. The higher speed corresponds to a 40" machine at 1200 to 1250 r. p. m.; a common practice on the mainland.

The following tests of the time required for drying were made running at the lower speed, approximating factory conditions.

TABLE 3.

No. 1, $\frac{3}{4}$ charge	Time, 1 hour	Drying fair
No. 2, Full charge	Time, $1\frac{1}{4}$ hours	Drying rather better
No. 3, Full charge	Time, $1\frac{1}{2}$ hours	Drying better than No. 1

After these trials the centrifugal was speeded to 1275 r. p. m. to obtain the molasses, which was to be reboiled in the experimental apparatus at this Station, without unnecessary delay. The quality of the sugar was not improved but the molasses from a full charge was obtained in from 40 to 50 minutes. Molasses samples from the different buckets of massecuite were of the following purities:

TABLE 4.

Brix	Gravity Purity
87.5	36.6
88.8	36.8
89.0	35.6

This molasses as it came from the centrifugal, contained considerable amounts of fine grain which had passed through the screen. Reanalysis of the last of the above samples, after removing this grain, indicated that the gravity purity of the molasses was 33.8. The final molasses was faintly alkaline to litmus.

TABLE 5.

	Purities						Glucose	Ash	Glucose	Ash	% CaO	% P ₂ O ₅
	Brix	Apparent	After Kieselguhr	Gravity	True	Suspended Solids						
First Mill Juice	....	67.2	....	....	....	....	....	....	....	....	....	....
Last Mill Juice	6.2	49.9	53.5	....	....	0.66	....	....	....	....	....	....
Last Mill Juice after screening	5.71	53.3	54.7	54.1	....	0.20	0.75 *	0.75 *	0.27 *	2.77 *	0.017	0.030
Clarified juice	5.61	57.2	58.0	57.8	....	....	0.75 *	0.75 *	0.32 *	2.33 *	0.038	0.008
Syrup	72.5	58.6	....	59.7	64.1	....	11.60	11.60	4.51	2.59	0.57	0.14
Masseuite when boiled	96.0	58.0	....	60.4	65.7	....	14.43	14.43	5.90	2.45	0.75	0.16
Masseuite Dec. 21	....	58.0	....	60.7	....	....	....	....	....	....	....	....
Sugar	97.3	76.3	....	78.6	81.9	....	7.00	7.00	4.00	1.75	....	....
Molasses Nov. 25	....	....	....	34.0	....	....	....	....	....	....	....	....
Molasses Dec. 12	....	....	....	36.3	....	....	....	....	....	....	....	....
Molasses Dec. 12 with grain removed	89.2	27.8	....	33.8	39.2	....	22.5	22.5	9.23	2.44	1.89	....
Molasses after reboiling Jan. 25	93.6	....	....	27.77	31.0	....	22.8	22.8	11.0	2.07	....	....

* These figures are not comparable with corresponding figures for syrup, for ash and glucose determinations on runs 1 and 3 were lost.

The sugar was 76.3 apparent and 78.6 gravity purity. Securing a sugar dried to this purity under conditions approximating factory practice from a massecuite containing so much false grain and in which the mother liquor was reduced to thirty-four gravity purity was a somewhat better result than could reasonably have been expected.

Averages of the analyses made during this work appear in accompanying tabulation. The figures for ash and glucose in the juice are not, however, directly comparable with the corresponding figures for syrup, for in runs 1 and 2 these determinations in the juices were lost. In order that comparison involving the use of ash and glucose content may be made, figures for runs 4, 5 and 6, which are comparable, are tabulated below:

TABLE 6.

	Brix	Sucrose	Gravity Purity	Glucose	Ash	Glucose Ash	Sucrose Ash
Screened juice	5.71	3.24	56.7	0.75	0.27	2.77	12.0
Clarified juice	5.55	3.27	59.0	0.75	0.32	2.33	10.2
Syrup	73.18	45.01	61.37	10.60	4.02	2.64	11.2

The molasses secured from this experiment was submitted to the same treatment that has been used in studying other samples of molasses at this Station. This consists of concentrating, seeding with fine grained sugar and, after crystallizing in motion under carefully controlled temperature conditions, separating the mother liquor. The tabulated results follow:

TABLE 7.

	Molasses	Concen- trated Molasses	Chek	Final Molasses
Brix	88.2	96.7	95.4	93.65
Sucrose	32.40	35.94	35.52	26.01
Gravity Purity	36.74	37.17	37.23	27.77
Total Solids	79.89	87.02	87.03	83.87
True Purity	40.56	41.30	40.81	31.01
Glucose	20.78	21.51	20.49	22.77
Ash	8.79	9.55	10.04	10.99
Org. Non-Sugar	17.92	20.02	20.98	24.10
Sucrose: Ash	3.69	3.76	3.54	2.37
Glucose: Ash	2.36	2.25	2.04	2.07
O. N. S.: Ash	2.04	2.10	2.09	2.19
Water	20.11	12.98	12.97	16.13
Sucrose: Water	1.61	2.77	2.74	1.61

The first column is the analysis of the molasses before treatment, the second after concentration, the third the unseeded sample placed in the crystallizer to detect changes during crystallization and the last column the analysis of the molasses separated from the seeded and crystallized massecuite.

The results do not differ in any material respect from those of a number of other samples that have been similarly treated. There was no destruction of sucrose during boiling, but the usual small destruction of sucrose during crystallization may be noted. There was also the usual small destruction of glucose during boiling and a somewhat greater than the average destruction of glucose during crystallization. The gravity purity was reduced to 27.77, a figure within some two points of as low as any samples of Hawaiian molasses which have been reduced by this method. Judged by the above figures this molasses can hardly be classed as abnormal for all the characteristics shown lie within the limits of other samples of Hawaiian molasses that have been similarly treated.

The work done at the Kaluku factory developed the following points. The actual purity of the last mill juice was higher than indicated by the ordinary analysis because of the effect of the suspended matter on the brix. The total increase in purity obtained by screening and clarification was very large. In the more dilute juices in runs 1 and 2 the increase was from 50% to 100% greater than in the more concentrated juices in later runs. The larger increase in purity in the more dilute juices seems to be due both to the relatively greater effect of the suspended solids on the brix and a greater removal of soluble impurities. Figures for runs 4, 5 and 6 indicate a small increase in ash during clarification and a small decrease during evaporation. Glucose remained unchanged during clarification, increased slightly during evaporation, and decreased during both boiling and crystallization. The differences noted between clarified juice and syrup, however, may be considered within the limits of experimental error when the large differences in the concentration of the samples analyzed are taken into consideration. With the exception of the small increase in glucose during evaporation, which as just noted is hardly beyond the limits of experimental error, none of the figures gives any indication that any material amount of sucrose has been destroyed. In particular the analysis of a portion of the massecuite on December 23, demonstrates that the reduction in the purity of the molasses was due to crystallization of sucrose and that no loss had occurred while the massecuite was maturing. The loss of sucrose in run number 2 is not taken into consideration in making the above comments. The conditions which caused this loss were accidental and would not ordinarily be encountered in well conducted factory operations. This experiment demonstrated that with well conducted factory work a much larger yield of sugar could be obtained from the last mill juice than would be inferred from its purity, for even though final molasses of normal purity were assumed, an increase of over 10 points between the apparent purity of the raw juice and the gravity purity of the massecuite would hardly be expected. Assuming commercial sugar of 98 gravity purity, no losses in manufacture, and reduction of the molasses to 33.8 gravity purity, the S. J. M. formula indicates a yield of 67% of the sucrose in

this last mill juice, originally of 49.9 apparent purity. Further, the work at this Station failed to develop any particularly abnormal characteristics in the molasses.

In estimating the value of the last mill juice from the results of this experiment there is some question as to whether or not the removal of a part of the cuscush before clarification is the equivalent of present milling practice. No data is available as to whether a considerable part of the cuscush is removed when the last mill juice is used as maceration and rescreened or whether the cuscush is carried on into the mixed juice. Undoubtedly more or less of a screening action does take place when the juice is applied as maceration and, in the writer's opinion, screening juice before clarification makes the results of the experiment more nearly comparable to the results actually secured in factory practice, than would have been the case had the cuscush been removed subsequent to clarification. Had the latter course been adopted this experiment would have been to a considerable extent a study of the effect of organic impurities dissolved through the action of lime and heat instead of a study of the effect of the soluble impurities in the last mill juice. In this connection, it should be noted that present screening practice leaves much to be desired. With an improvement in screening practice any discrepancy between the results of this experiment and factory practice would be removed.

This experiment was conducted under decidedly abnormal conditions so far as the quality of the cane was concerned, and the results must be used with a considerable degree of caution in estimating the value of last mill juice under normal conditions. According to all present information when cane of good quality is ground, the glucose content of last mill juice is lower than was the case during this experiment. While data at this Station indicates that undue importance is often given the role played by glucose in the formation of molasses, it is undoubtedly easier to reduce the final molasses resulting from last mill juice, high in glucose, to a low purity than it is in the case of juices of lower glucose content. To just what extent the lower glucose content will affect the results can only be determined by experiment and it is planned to repeat the experiment at an early date using last mill juice resulting from normal cane and higher extraction.

Nitrogen Increases Yield at Grove Farm.

GROVE FARM EXPERIMENTS 2, 3, 4, AND 5, 1922 CROP.

By J. H. MIDKIFF.

SUMMARY.

These experiments, covering a period of six years and consisting of three crops, plant cane, first, and second ratoons, deal with nitrogen applications. Amounts to apply, the time of application and forms of nitrogen have been studied. The results of the plant cane experiments were printed in *The Record*, Volume XIX, page 270, and the results of the first ratoon trials were printed in Volume XXII, page 307.

The cane was D 1135, the 1922 crop being the second ratoons. The previous crop was harvested in April, 1920. It was cut back in July. Although the experiment schedule called for four applications of fertilizer, two the first season and two in the second, only two applications were made in all (with the exception of Experiments 3 and 4, dealing with the time of application). One application was made in October 1920, and the other three combined in March 1921. The cane in all plots received a uniform dose of 500 pounds reverted phosphate per acre.

The results of the different treatments follow:

Experiment 2. Amount to Apply.

Plots	Treatment	Yield per Acre			Gain Over No Fertilizer	
		Cane	Q. R.	Sugar	Cane	Sugar
X	No fertilizer	27.66	7.55	3.66	....	....
A	1000 lbs. nitrogen mixture	35.69	7.93	4.50	8.03	0.84
B	2000 lbs. nitrogen mixture	35.03	7.87	4.45	7.37	0.79

Experiment 3. Time of Application.

Plots	Treatment	Cane	Q. R.	Sugar
A	1000 lbs. nitrogen mixture in three doses, 250 lbs. in October, 500 lbs. in March and 250 lbs. in June..	39.51	8.15	4.85
C	1000 lbs. nitrogen mixture in two equal doses second season, March and June. No fertilizer first season	35.98	7.87	4.57
D	1000 lbs. nitrogen in two equal doses: one in October first season and one in March second season	34.94	7.54	4.63

Experiment 4. Amount to Apply Second Season.

Plots	Treatment	Cane	Q. R.	Sugar
C	1000 lbs. nitrogen mixture applied in one dose in March	37.59	7.77	4.84
E	500 lbs. nitrogen mixture applied in one dose in March	37.92	7.44	5.10

Experiment 5. Forms of Nitrogen.

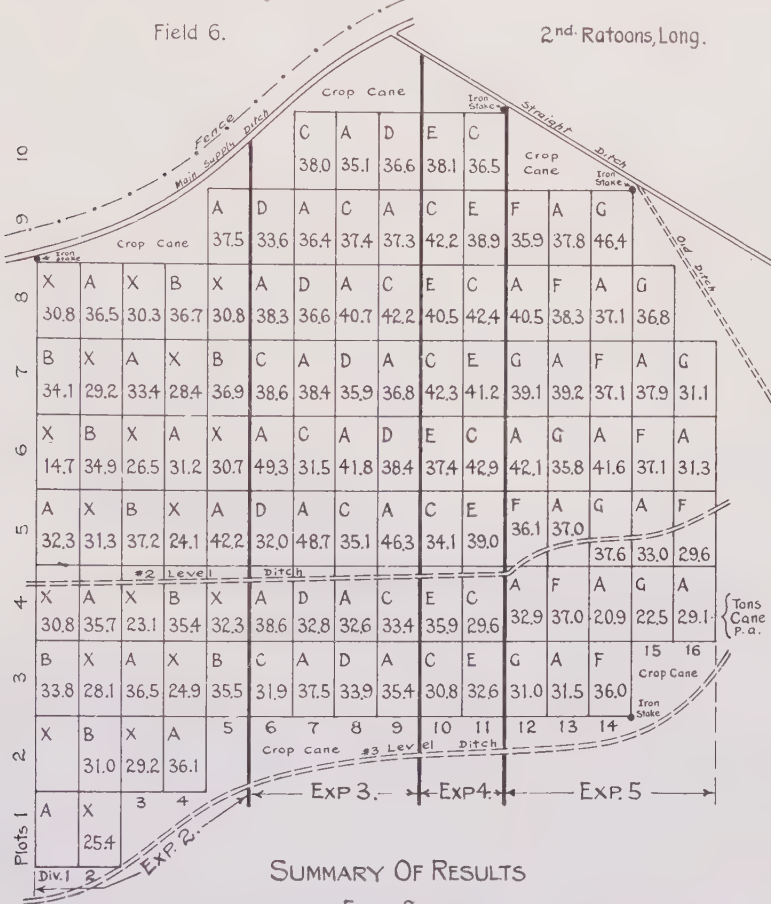
Plots	Treatment	Cane	Q. R.	Sugar
A	1000 lbs. nitrogen mixture, 250 lbs. in October and 750 lbs. in March, 1921	35.1	8.14	4.31
F	1000 lbs. nitrogen mixture applied in one dose in October, 1920	35.86	8.41	4.26
G	1250 lbs. dried blood, 12% nitrogen, applied in one dose, October, 1920	35.02	8.96	3.91

The harvesting results of Experiment 2 show that 150 pounds of nitrogen gave an increase of over eight tons of cane and .84 ton of sugar per acre over no nitrogen. In the first ratoon 177 pounds of nitrogen gave an increase of .70 ton of sugar over 27 pounds of nitrogen. There was an increase of only .10 of a ton of sugar from the application of 150 pounds of nitrogen in the plant cane. While the addition of 150 pounds of nitrogen increased the sugar yield only 1.3 percent in the plant cane, it increased it 13 percent in the first ratoon and 23 percent in the second ratoon.

In the plant cane and both the ratoon crops, 300 pounds of nitrogen gave slightly less than 150 pounds of sugar per acre. This was due to the fact that the heavier dose of nitrogen lowered the purity of the juices, as the weight of the cane in the 150 pound and the 300 pound plots was practically the same in all cases.

A study of the results of Experiment 3 for the three crops does not prove conclusively the proper time of applying nitrogen. In the plant crop the cane in all plots was of practically the same weight. But the heavy doses the second season caused the juices of the C plots to be poorer and caused a resulting decrease in sugar. In the first ratoon the juice from the C plots which received all their fertilizer the second season was as good as that of the D plots which received all their fertilizer the first season. And in this case the C plots, having more cane, produced more sugar. In the second ratoons the A plots received one-fourth of their fertilizer the first season and three-fourths the second. And in spite of their having the poorest juices, they had enough more cane to overbalance the C and D plots, which had considerably better juices and which received their fertilizers in two doses, the former all in the second season and the latter, half in the first and half in the second season.

GROVE FARM PLANTATION EXPTS. 2,3,4&5, 1922 CROP
 EXP. 2. AMOUNT TO APPLY. EXP. 3. TIME OF APPLICATION.
 EXP. 4. AMOUNT TO APPLY. EXP. 5. FORMS OF NITROGEN.



SUMMARY OF RESULTS

EXP. 2.

Plots	No. of Plots	Treatment	Yields Per Acre		
			Cane	G.R.	Sugar
X	18	No Fertilizer	27.66	7.55	3.66
A	10	1000 lbs. Nitrogen Mixture	35.69	7.93	4.50
B	9	2000 lbs. Nitrogen Mixture	35.03	7.87	4.45

EXP. 3.

Plots	No. of Plots	Treatment			Yields Per Acre		
		October 1920.	March 1921.	June 1921.	Cane	G.R.	Sugar
A	15	250* Nit. Mixt.	500* Nit. Mixt.	250* Nit. Mixt.	39.51	8.15	4.85
C	8	—	500* Nit. Mixt.	500* Nit. Mixt.	35.98	7.87	4.57
D	8	500* Nit. Mixt.	500* Nit. Mixt.	—	34.94	7.54	4.63

EXP. 4.

Plots	No. of Plots	Treatment	Yields Per Acre		
			Cane	G.R.	Sugar
C	8	1000 lbs. Nitrogen Mixture - March 1921.	37.59	7.77	4.84
E	8	500 lbs. Nitrogen Mixture - March 1921.	37.92	7.44	5.10

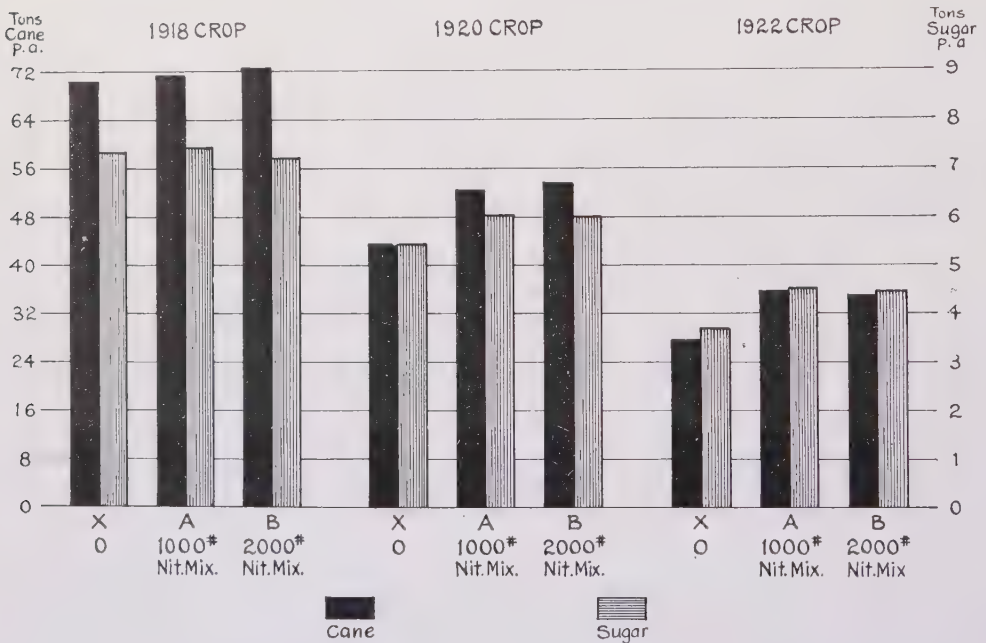
EXP. 5.

Plots	No. of Plots	Treatment	Yields Per Acre		
			Cane	G.R.	Sugar
A	14	250* Nit. Mixt. Oct. 1920., 750* Nit. Mixt. March	35.10	8.14	4.31
F	8	1000 lbs. Nitrogen Mixture - October 1920.	35.86	8.41	4.26
G	8	1250 lbs. Dried Blood 12% N. October 1920.	35.02	8.96	3.91

The cane of Experiment 4 received all of its nitrogen the second season. In all three crops the cane in the C and E plots was practically the same. But the E plots, receiving only half the amount of nitrogen as the C plots, invariably had better juices and produced more sugar per acre.

In Experiment 5, comparing the forms of nitrogen, dried blood did not give quite as good results for the three crops as a nitrogen mixture. The blood was applied in one dose the first season, while the nitrogen mixture was applied in one dose to the F plots and in four doses to the G plots, (G plots in second ratoon received nitrogen mixture in two doses). With the exception of the first ratoon crop, the nitrogen mixture both in the A and F plots produced better juices than the dried blood.

AMOUNTS OF NITROGEN
GROVE FARM PLANTATION EXP. 2, 1918, 1920 & 1922 CROPS



GROVE FARM PLANTATION CO. EXPERIMENT 2, 1922 CROP.

Fertilizer Experiment — Amount to Apply — Second Ratoons.

0, 150, 300 lbs. nitrogen per acre.

Object:

To determine the most profitable amount of nitrogen to apply to ratoon cane.

Location:

Field 6.

Crop:

D 1135, 2nd ratoons, long.

Layout:

Number of plots: 37.

Size of plots: 1/10 acre each (90.2'x 48.3').

Plots one watercourse wide and end boundaries marked by small stakes in cane rows. Rows irregular.

Plan:**Fertilization — Pounds N. M. per Acre.**

Plot	No. of Plots	October 1920	March 1921	May 1921	Total Pounds Nitrogen
X	18	...	...	...	...
A	10	250	750	250	150
B	9	500	1,500	500	300

Fertilizer used: Nit. mix., 15% N. (6% nit., 6% sul., 3% org.).

All plots received a uniform dose of 500 pounds of reverted phosphate per acre in October, 1920.

Experiment originally planned and laid out by L. D. Larsen.

Experiment revised by R. S. Thurston and J. A. Verret.

Experiment conducted by J. H. Midkiff.

Chemical analyses by A. H. Chase.

GROVE FARM PLANTATION CO. EXPERIMENT 3, 1922 CROP.*Fertilizer Experiment — Time of Application.***Object:**

To determine the best time to apply a given amount of fertilizer to ratoon cane.

Location:

Field 6.

Crop:

D 1135, 2nd ratoons, long.

Layout:

Number of plots: 31.

Size of plots: 1/10 acre each (90.2'x 48.3').

Plots one watercourse wide and bounded at ends by small stakes in cane rows. Rows irregular.

Plan:**Fertilization — Pounds N. M. per Acre.**

Plot	No. of Plots	October 1920	March 1921	Total Pounds Nitrogen
A	15	250	500	150
C	8	...	500	150
D	8	500	500	150

Fertilizer: 15% N. (6% nit., 6% sul., 3% blood).

Experiment originally planned by L. D. Larsen.

Experiment revised by R. S. Thurston and J. A. Verret.

Experiment conducted by J. H. Midkiff.

Chemical analyses by A. H. Chase.

GROVE FARM PLANTATION CO. EXPERIMENT 4, 1922 CROP.

*Fertilizer Experiment—Amount to Apply—Second Season.***Object:**

To determine the most profitable amount of fertilizer to apply to ratoon cane during the second season.

Location:

Field 6.

Crop:

D 1135, 2nd ratoons, long.

Layout:

Number of plots: 16.

Size of plots: 1/10 acre each (90.2'x48.3').

Plots one watercourse wide and bounded at ends by small stakes in cane rows. Rows irregular.

Plan:**Fertilization—Pounds N. M. per Acre.**

Plot	No. of Plots	Aug. 1920	Nov. 1920	March 1921	Total Nitrogen
C	8	....	....	1,000	150
E	8	....	....	500	75

Fertilizer: 15% N. (6% nit., 6% sul., 3% org.).

Experiment originally planned and laid out by L. D. Larsen.

Experiment revised by R. S. Thursten and J. A. Verret.

Experiment conducted by J. H. Midkiff.

Fertilizer analyses by A. H. Chase.

GROVE FARM PLANTATION CO. EXPERIMENT 5, 1922 CROP.

*Fertilizer Experiment—Forms of Nitrogen.***Object:**

To compare the relative value of equal amounts of nitrogen from the following sources: organic (dried blood) and a 15% nitrogen mixture composed of 6% from nitrate, 6% from sulfate and 3% from blood.

Location:

Field 6.

Crop:

D 1135, 2nd ratoons, long.

Layout:

Number of plots: 30.

Size of plots: 1/10 acre each (90.2'x48.3').

Plots one watercourse wide and bounded at ends by small stakes in cane rows. Rows irregular.

Plan:**Fertilization—Pounds per Acre.**

Plot	No. of Plots	Fert.	October 1920	March 1921	Total Nitrogen
A	14	N. M.	250	750	150
F	8	N. M.	1,000	...	150
G	8	Blood	1,250	...	150

Fertilizer: Nit. mix., 15% N. (6% nit., 6% sul., 3% blood); blood 12% N.

Experiment originally planned and laid out by L. D. Larsen.

Experiment revised by R. S. Thursten and J. A. Verret.

Experiment conducted by J. H. Midkiff.

Fertilizer analyses by A. H. Chase.

Juice Extraction by Centrifugal Force.

By H. D. BEVERIDGE.

During the 1921 crop at Onomea several experiments were carried on with shredded cane to determine the amount of juice that could be separated by centrifugal force, in an ordinary centrifugal.

Cane was passed directly into the shredder, in order to get the shredded product from cane that had not passed through the crusher. This was analyzed for percent sugar, moisture and fiber. About 150 pounds was weighed, and spun for twenty minutes in an ordinary 40" Mackintosh centrifugal at 1100 R. P. M. The free juices thrown off were weighed to determine the percent extraction, and analyzed for Brix, sugar and purity.

The residue was washed in the centrifugal with 50 percent of its original weight of water, and spun for fifteen minutes after the water was stopped. The resultant bagasse was removed, weighed, and analyzed for percent sugar, moisture and fiber.

Experiment No. 1 was not washed, as we found, after spinning some time, that the centrifugal was not properly cleaned out, and it was necessary to weigh the bagasse instead of the juice to determine the extraction. In the other tests the juice extraction was determined by weighing free juices thrown off as above described.

The results of these experiments may be of interest and are tabulated next page:

Sample	1 *	2	3	4
Shredded Cane—				
Weight (lbs.)	150.0	153.0	149.0	151.5
Polarization	11.93	10.86	11.69	10.00
Moisture	71.0	74.8	72.4	72.0
Fiber	13.35	12.70	14.25	12.75
Undiluted Juice—				
Brix	20.97	15.82	16.15	18.50
Polarization	16.09	12.93	13.72	15.46
Purity	76.7	81.8	84.9	83.6
Pounds bagasse before washing	72.0	86.0	85.0	82.0
Pounds undiluted juice extracted	78.0	67.0	64.0	66.5
Wash water added % cane .....	.....	50	50	{ ½" hose 5 min.
Time of spinning after washing (minutes) ..	.....	15	15	
Final Bagasse—				
Polarization	9.42	4.44	7.35	5.47
Moisture	58.4	67.0	65.0	66.0
Fiber	29.4	25.5	26.25	27.0
Weight (lbs.) .....	.....	78.5	77.0	78.0
Extraction Data—				
Undiluted juice % cane	52.0	43.8	43.0	43.9
Total extracted juice % cane	52.0	48.7	48.3	48.5
Juice extracted % juice in cane	60.0	55.8	56.3	55.6
Pol. extracted % pol. in cane	62.1	79.0	67.5	71.8
Speed of Centrifugal (R. P. M.)	1110	1080	1095	1104

* This sample was not washed. The analysis is that of the bagasse remaining after the undiluted juice was thrown off.

It is shown by actual tests, that it is possible to extract nearly eighty percent of the total sugar in shredded cane by means of an ordinary centrifugal at 1100 R. P. M., exerting about 700 pounds pressure per square inch. What extraction could be obtained with an apparatus capable of double or treble that speed?

Papaikou, October 20, 1921.

Why Do Rats Eat Cane?

By EDW. L. CAUM.

It is undeniable that rats are an exceedingly undesirable part of the population of a cane field, but it is an open question as to whether they are wholly responsible for all the damage that is laid at their door. It is not known just what part the cane plays in the rat's domestic economy — whether it is an important part of his diet or whether it is not. For the purpose of throwing a little light on this question, the experiment detailed below was carried out.

On December 28, 1921, the Experiment Station possessed ten white rats (the albino form of the common brown rat), consisting of four males and six females. Their exact age was not known, but was somewhere between three and four months. On that date four of these animals, two males and two females, were placed in another cage and fed on sugar cane and water exclusively. The remaining six rats were kept as checks, being fed their regular diet, which consisted mainly of bread, with various extras in the way of canna roots, pualele (*Sonchus*), lettuce and the like.

On February 18, 1922, the fifty-third day of this selective feeding, the experiment was discontinued, and the experimental animals carefully compared with the checks. The four rats which had been fed on cane alone were small, sluggish, unsteady on their feet, and scarcely able to open their eyes wide. Their fur was yellowish, and they showed all the signs of being in an extremely unhealthy condition. They had not bred, or if they had the young had been eaten immediately after birth. There was never any sign of young noted in the cage. The check animals, on the other hand, were much larger and were very active and alert. Their fur was the pure white that it should be, and each of the females had produced a good-sized litter of young. The difference in the appearance of the two lots was striking, but an even more striking difference was noted when the animals were weighed. The four rats from the experimental cage weighed, respectively, 66, 64, 51 and 40 grams, an average of 55.25 grams each. Four of the check animals, and not the four largest, weighed 171, 154, 150 and 135 grams, an average of 152.50 grams each, or nearly three times the weight of the cane-fed rats.

During the two weeks between February 18 and March 4, the four experimental animals were given the same diet as those in the check cage. At the end of the first week they weighed 82, 81, 62 and 54 grams, averaging 69.75 grams each, having gained a trifle over 26% in one week of feeding on a mixed diet. At the end of the second week they weighed 95, 90, 71 and 58 grams, an average of 78.50 grams each. This represents a further gain of 12.55% over their weight of the week before, or a total gain of 42.81% in the two weeks of feeding on a more balanced ration. This seems to indicate that sugar cane is certainly not a very important part of the rats' menu.

From the condition of the experimental animals after fifty-two days on an exclusive sugar cane diet, and from the way their condition improved in two

weeks on a mixed diet, it looks very much like a case of partial starvation. The animals themselves gave the clue to the critical substance that was lacking in the manner in which they attacked the cane given them. They would first gnaw out the eyes, and then scrape the root-band clean, before eating out the pith. In other words, they first ate the embryonic tissue, the protein-bearing part of the cane stalk. This is a decided contrast to the habits of the field rats, which gnaw out the pith from the internodes, leaving the nodes untouched. The accompanying illustration clearly shows this contrast.

This experiment seems to indicate that rat damage to sugar cane is after all incidental, and that the animals can easily exist in a cane field without making use of the cane as an article of diet at all. The various insects and weeds present in the fields would furnish them with a completely balanced ration.

However, it is certain that rats do destroy a large amount of cane, and when we seek the reason, borers should be given the first consideration. The larvae of these insects are a very acceptable article of food for rats, and it is entirely possible that the rats learned to eat cane in the course of their excavating the stalks in search of these larvae. Various theories have been advanced concerning the relation between rats and borers. One is that the rats eat cane as an ordinary article of food—make it an integral part of their diet, and that the cane so damaged attracts the borers, because the gnawed portions greatly facilitate egg-laying. In other words, the borers follow the rats. Another theory is just the reverse of this. According to this, the borers were there first, and the rats attack the cane, hollowing out the joints in their search for the borer larvae. It is a well-known fact that insects are an important part of a rat's diet. Rat-eaten cane in the field, if not too badly fermented and covered with fungi, will frequently show traces of borer infestation. In the stick shown at the left of the illustration there were very evident traces of borers in two joints. The others were too badly gnawed to make a definite determination of this point possible.

A slight bit of additional evidence in favor of the second hypothesis may be seen in the following incident. In the course of the feeding experiment just described, a piece of cane containing a borer larva was given to the check rats. Although these animals had never seen a borer larva before, they showed no hesitation at all in consuming this one, and then they completely hollowed out the joints through which the borer had worked before making any attempt to eat into the sound joints above. When they had finished with the stick, it looked very much like the rat-eaten cane found in the fields. This may indicate why rat-eaten cane does not more commonly show evidences of previous borer infestation.



The two sticks on the left are rat-eaten cane from the fields. Note that the internodes are well hollowed out, but the eyes and root-bands are intact. Note the borer channel at the top of the stick on the left. Borer larvae had been through the middle internode of this stick as well.

Those to the right are specimens of the cane eaten by the experimental rats. Note how the eyes are gnawed out and the root-bands scraped clean.

Plows vs. Hoes.

By J. A. VERRET.

ONOMEA EXPERIMENT NO. 12, 1922 CROP.

This experiment was planned by the plantation and conducted by it, except that the Station fertilized the plots and harvested the experiment. The labor distribution in the different operations was kept by the plantation.

The experiment consisted of twelve plots, each 1/10 acre. There were six repetitions of each treatment. The cane was Yellow Caledonia, first ratoons, long. All plots were shaved with a stubble shaver, after which the experimental treatments were begun. All plots were fertilized as follows:

September 11, 1920	February 1, 1921	June 1, 1921
500 lbs. B 7 *	500 lbs. B 7 *	400 lbs. Nit. Soda
200 lbs. Pt. Nit.		

* B 7 = 11% N., 6% P₂O₅, 6% K₂O.

The labor distribution in hours per acre is as follows:

	Plantation Practice		Hoes Only Men
	Men	Animals	
Off-barring	6.95	6.95	.....
Cultivating	15.96	15.96	.....
Fertilizing	8.22	.....	8.50
Covering Fertilizer	13.33	3.33	22.20
Hoeing	102.39	.....	234.10
Harrowing	5.15	5.15	.....
Hilling plows	8.33	8.33	.....
Hilling hoes	4.80	.....	.....
Total	165.13	39.72	264.80

The yields obtained are given in the following tabulation:

Treatment	Yield per Acre		
	Cane	Q. R.	Sugar
Plantation Practice	50.1	10.18	4.92
Hoes Only	54.0	9.73	5.55

From the above we see that the plows were actually detrimental to yields, and that hoes only were more expensive and used up much more man labor, which is something to be avoided at the present time.

The logical method of procedure would therefore seem to be to cover fertilizer and control weeds as much as possible with surface implements to avoid disturbance to the root systems of the growing cane.

Evidently the benefits, if any, derived from the use of plows is not great enough to make up for the check caused by root destruction. This is indicated to some extent by notes taken in this field on December 24, 1920, by W. L. S. Williams.

Mr. Williams states: "In the cultivation experiment (Exp. No. 12, 1922 crop) the X plots which have received off-barring and regular plantation cultivation have far better color, but the A plots, where no animal work has been done, are noticeably higher in growth."

DETAILS OF EXPERIMENT.

Object:

To determine the value of cultivation practices comparing:

1. Plantation practice, including off-barring, middle-breaking and hilling (X).
2. No animal cultivation—hoeing only (A).

Location:

Onomea Sugar Co., Field 82.

Crop:

Yellow Caledonia, 1st ratoons.

Layout:

Number of plots—26.

Size of plots—1/10 acre, consisting of 6 lines, each line 5.93 ft. wide and 122.5 ft. long. Lines 1 and 6 are guard lines, to be discarded on harvesting, and lines 2, 3, 4 and 5 of each plot harvested as experiment.

Plan:

Fertilization:

Uniform to all plots, and to be applied by Station representative as follows:

Sept. 20, 1920—500 lbs. B-7 per acre and 200 lbs. Pot. Nit.

Dec. 1, 1920—500 lbs. B-7 per acre.

April 1, 1921—400 lbs. N. S. per acre.

B-7=11% N.; 6% P_2O_5 , 6% K_2O .

N. S.=15.5% N.

Cultivation:

Time to be kept separately for A and X plots by plantation team-luna. Station representative to be present whenever possible.

Cultivation Practices.

HALAWA PLANTATION EXPERIMENT NO. 1, 1922 CROP.

Various cultivation practices were compared in this test. In one series of plots the so-called plantation practice was followed. This included offbarring and hilling. In a second series, cultivators were used for weeding and for covering the fertilizer. No plows were used. In the third series of plots no animals were used, the weeding and covering of the fertilizer being done by hoes.

The cane was Yellow Caledonia, first ratoons, long, and was harvested in February 1922, at the age of 23 months. The previous crop was harvested in March 1920.

On August 12 to 14, all the plots were hoed, then on the 17th, the X plots were offbarred and on August 20, all plots received 500 pounds per acre of complete fertilizer. The fertilizer in the X and A plots was covered with a cultivator, while in the B plots it was done with hoes. In covering the fertilizer, the cultivator was run twice on each row. All plots were hoed the second time on October 6 and on the 7th all plots were fertilized. The fertilizer on the X plots was covered with plows in the hilling up, that on the A plots was covered with cultivators as previously, and that in B with hoes.

The labor distribution in hours per acre for these different operations is given as follows:

	X PLOTS Plantation Practice		A PLOTS Cultivators and Hoes		B PLOTS Hoes Only	
	Men	Animals	Men	Animals	Men	Animals
Hoeing	16.2	....	16.4	....	16.5	....
Applying fertilizer	4.0	....	4.0	....	4.0	....
Covering fertilizer and hilling ..	8.8	8.8	6.3	6.3	17.3	....
Offbarring	7.7	7.7	....	....	....	....
Total	36.7	16.5	27.7	6.3	37.8	0.0

The yields per acre obtained are given in the following table:

Plots	Treatment	Yield per Acre		
		Cane	Q. R.	Sugar
X	Offbarring, plowing, etc.....	29.8	8.07	3.70
A	Cultivators and hoes, no plows	29.3	8.01	3.65
B	Hoes only	29.0	8.09	3.59

The yields were substantially the same for all treatments. By omitting offbarring and hilling and controlling weeds as much as possible with cultivators, a distinct saving in labor was shown, and is to be preferred to either of the other methods.

In order to see if plowing becomes necessary in time we plan to continue this experiment in the same way until the field is again plowed for planting.
J. A. V.

Preliminary Investigations in Seed Germination.

By WM. W. G. MOIR.

Single eye cuttings have been used in our study of the heritable characters of the progenies in the bud selection project. They have been started in pots and later set out in the field a uniform distance apart. Only plants of a uniform size and vigor were planted out so as to insure an even stand in each progeny. To get a better understanding of the behavior of these cuttings, and seed in general as to treatments and methods of handling, so as to insure a quicker and more uniform germination, we have carried out a few experiments on germination of these cuttings.

Nursery flats holding nine single eye cuttings of H 109 cane were used throughout the experiments and the sand-soil mixture of one part sand to four parts soil was used in all cases where the treatment did not call for some other soil medium. In all treatments sufficient repetitions and checks were made, and seed from different stalks and stools was well mixed to insure more uniform and trustworthy results. Observations and recording of germinations were made from day to day for a period of six weeks, at which time the experiments were abandoned. The results obtained are applicable only to material handled under the above conditions, but many suggestions may be obtained for plantation practice. We intend carrying out a few of these in further field tests at Waipio later on this year.

An outline of the object and results of each of the experiments follows:

Experiment 1.

Object:

Single eye cuttings vs. three joint one eye cuttings (the two end eyes gouged out), having the eye:

- (1) On the top of the cutting when placed in the flat.
- (2) On the side of the cutting when placed in the flat.
- (3) On the bottom of the cutting when placed in the flat.

Results:

1. Cuttings placed so that the eyes were on the top germinated one week sooner than those on the side, and two weeks sooner than those on the bottom and maintained this lead throughout the six-week period.
2. Single eye cuttings germinated sooner than the three joint one eye cuttings, but the three joint cuttings grew faster after germination and soon surpassed the one joint cuttings in growth.
3. Germinations were much better from eyes turned up or on the side than from those turned down.
4. Shoots arising from the three joint one eye cuttings were much more vigorous and larger than those from the single eye cuttings.

*Experiment 2.***Object:**

1. Single eye cuttings cut close to the node vs. those cut as long as possible.
2. The above tried out under the following soil or planting media:
 1. Ordinary soil.
 2. Sterilized soil.
 3. Ordinary beach sand (coral).
 4. Sterilized beach sand (coral).
 5. Ordinary charcoal.
 6. Sterilized charcoal.
 7. Sand-soil mixture (1 to 4).
 8. Charcoal-soil mixture (1 to 4).

Results:

1. Long cuttings gave slightly better germination and more vigorous shoots than the short cuttings.
2. Soil media in order of germination rates are as follows: Charcoal, sand-soil, charcoal-soil, soil, and beach sand. In order of growth rate after germination: Sand-soil, soil, charcoal-soil, beach sand, charcoal.
3. No beneficial results were obtained from sterilizing the media.
4. The increased rate of germination in the charcoal flats was probably due to the greater absorption of heat by the black color, and the poor rate of growth afterwards to the lack of food.
5. The sand-soil mixture gave the best results and pure beach sand the poorest.

*Experiment 3.***Object:**

1. Single eye cuttings from the upper one-third of the stalk (top) vs. those from the middle one-third (body) vs. those from the lower one-third of the stalk (butt).
2. The above tried out under the following fungicidal treatments:
 1. Cuttings exposed to sunshine for one hour.
 2. Cut ends smeared with copper sulphate-starch paste.
 3. Cuttings dipped in bichloride of mercury for five minutes.
 4. Cuttings dipped in Bordeaux mixture for five minutes.
 5. Cut ends dusted with flowers of sulphur.
 - Bichloride of mercury — 1 to 1000.
 - Bordeaux mixture — 5-5-50.

Results:

1. Injurious effects were obtained in the treatments with copper-starch paste, bichloride of mercury, and Bordeaux mixture:
 - a. No germination in the copper-starch paste till the sixth week, when one eye germinated.
 - b. Only a 25 percent germination in the bichloride treatment.
 - c. Only 75 percent germination in the Bordeaux mixture.
2. Exposure to the sun for one hour had no bad effects nor any beneficial effects to the top seed, but had a retarding effect on the body and butt seed.
3. Flowers of sulphur was neither beneficial nor detrimental.
4. Top seed germinated quicker and gave a higher percentage of germination than body and butt seed.
5. Body and butt eyes were about equal in all treatments.

*Experiment 4.***Object:**

Top, body and butt seed unsoaked vs. top, body and butt seed soaked:

1. Ten minutes at 60° C.
2. Twenty-four hours in ordinary water
 - a. Left in long pieces.
 - b. Cut into single eye cuttings.
3. Forty-eight hours in ordinary water—
 - a. Left in long pieces.
 - b. Cut into single eye cuttings.

Seed soaked in long pieces was cut into single eye cuttings before planting.

Results:

1. Top eyes germinated quicker and gave a higher percentage of germination in all treatments except the ten minutes at 60° C. and the forty-eight hours (single eyes) soaking.
2. All eyes treated for ten minutes at 60° C. were damaged so badly that only three were able to germinate about the end of the sixth week.
3. Soaking for twenty-four hours had no beneficial effects over planting without soaking, and with long seed there was a slight retarding of germination.
4. Soaking for forty-eight hours with the seed cut into single eye pieces gave the maximum rate of germination for top, body and butt seed. This jump at the start over the rest of the treatments was maintained throughout the whole six weeks.
5. The seed left long and soaked did not compare with the single eye cuttings soaked; the period of soaking was not long enough, so no benefit was obtained and a slight retarding of germination resulted from this extra handling.
6. Body and butt seed soaked came up quicker and evenner than body and butt seed unsoaked.

*Experiment 5.***Object:**

Top, body and butt seed under the following treatments:

1. Single eyes cut and planted the same day that the material for treatment 2 was topped.
2. Single eyes from stalks, topped ten days before planting.
3. Single eyes from untopped stalks planted the day that treatment 2 was planted.

In topping the stalks for treatment 2 the cane top was removed for the top seed, the upper one-third of stalk for the body seed, and the upper two-thirds for the butt seed.

Results:

1. Germinations were recorded three days from planting in the topped seed.
2. One week after planting, the topped seed — top, body, and butt — had surpassed the seed planted seventeen days before. At the end of the six-week period the percentage of germination in the ordinary seed, cut and planted at the same time as topped seed, was only about two-thirds that of the topped, but the rate of growth had surpassed that of the topped seed.
3. Body and butt seed in the topped treatment gave a very high germination percentage and rate of growth. This was the best stand of body and butt seed throughout the whole five experiments.

General Conclusions.

1. Top seed is to be recommended in preference to body and butt seed, even in one year old cane, as was used in these tests.
2. Placing eyes on top, when single eye cuttings are used, is more beneficial than placing them on the side or bottom.

3. Soaking of seed, especially hard body and butt seed, for from forty-eight to seventy-two hours, changing the water daily, is strongly recommended. Soaking top seed is also beneficial, but is not necessary where the seed would have to be transported long distances to soak. Some form of tank car that could be hauled around to the different fields would overcome this transportation trouble.

4. Topping cane for a period of ten days prior to cutting seed is recommended only where there is a shortage of good seed. Rapid germination is obtained, but more careful handling and care after planting is necessary. The seed will germinate quickly, but the root growth is not fast enough to keep pace with the shoot and often the shoot dies or is set back. Extra irrigation will partially overcome this.

5. Hard body and butt seed should not be exposed to the sun, even when bagged, any longer than necessary. Cover the seed with trash.

6. Three joint one eye cuttings are recommended for single eye stooling investigation, as more vigorous shoots are obtained in a shorter time.

7. Soil-sand mixture of four to one is the best planting medium.

8. Flowers of sulphur is the only fungicidal treatment tried that can be recommended.

9. If single eye cuttings are to be used, cut them as long as possible.

10. Only vitally strong stalks should be used for seed. Very small stalks give poor results, and extra large suckers which are immature and soft may also lack vitality.

Most plantation men fail to realize the fact that top seed should be used in preference to body and butt seed; many of them are beginning to realize the importance of the size of the stalk used for seed; but very few agree on the question of soaking seed. There are plantations where no seed is planted that has not soaked for from 48 to 72 hours, and there are many that do not soak their seed at all, while in between we have them soaking seed from a few hours up to a day. Much more experimenting on this subject should be carried out. The harm that is done by the extra handling of soaking in the short periods more than balances the benefits derived from the soaking. To really get the benefits from soaking the seed must be completely penetrated, and this cannot be brought about in a few hours' soaking. From the results obtained in the tests above I am sure that seed should be either soaked from 48 to 72 hours or not soaked at all.

Experiments at Maui Agricultural Company.

By J. A. VERRET.

GENERAL.

These experiments were on the Maui Agricultural Company plantation, in field 83, Keahua section, at an elevation of about 500 feet. They were 1921 crop experiments, but on account of great delay in harvesting, due to abnormal labor conditions last year, it was necessary to carry them over to the 1922 crop. They were, therefore, harvested in January 1922.

During its growing period the cane in these experiments suffered a great deal from lack of water, more particularly during 1921, when the field received but two regular irrigations. The rainfall for the year in that section amounted to 24.76 inches, 18.47 inches of which fell in January, November and December. The cane dried up badly.

Therefore the results obtained from these experiments are to be considered as referring to conditions of extreme water and labor shortage, and are not necessarily the same as would be expected under normal conditions. The cane was plant, 27 months old at harvest.

The results obtained from this series of experiments are briefly summarized as follows:

First. Under conditions of labor and water shortage, and delay in harvesting from a sugar production point of view, H 109, Rose Bamboo, and D 1135 are of about equal value as plant cane. The selection of a variety for this section should therefore be based, to some extent, on the field and milling qualities of the cane. We should be inclined to favor H 109, as it is more likely to respond to better conditions. On the other hand, were conditions to remain bad, D 1135 would probably give better ratoons.

Second. Neither phosphoric acid nor potash produced enough increase in yield to pay for its cost.

Third. The economic limit in nitrogen was 175 pounds of this element per acre, equal to about 1,100 pounds of nitrate of soda.

Fourth. Applying a given amount of fertilizer in two doses gave better results than when applying it in three or four.

Fifth. Equal amounts of nitrogen from nitrate of soda, ammonium sulphate, a mixture of equal amounts of nitrate and sulphate, and dried blood gave about equal yields of sugar. The blood was the most expensive.

EXP. 4 VARIETY TEST.

EXP. 5. AMOUNT TO APPLY.

EXP. 6. PROPORTION EACH SEASON.

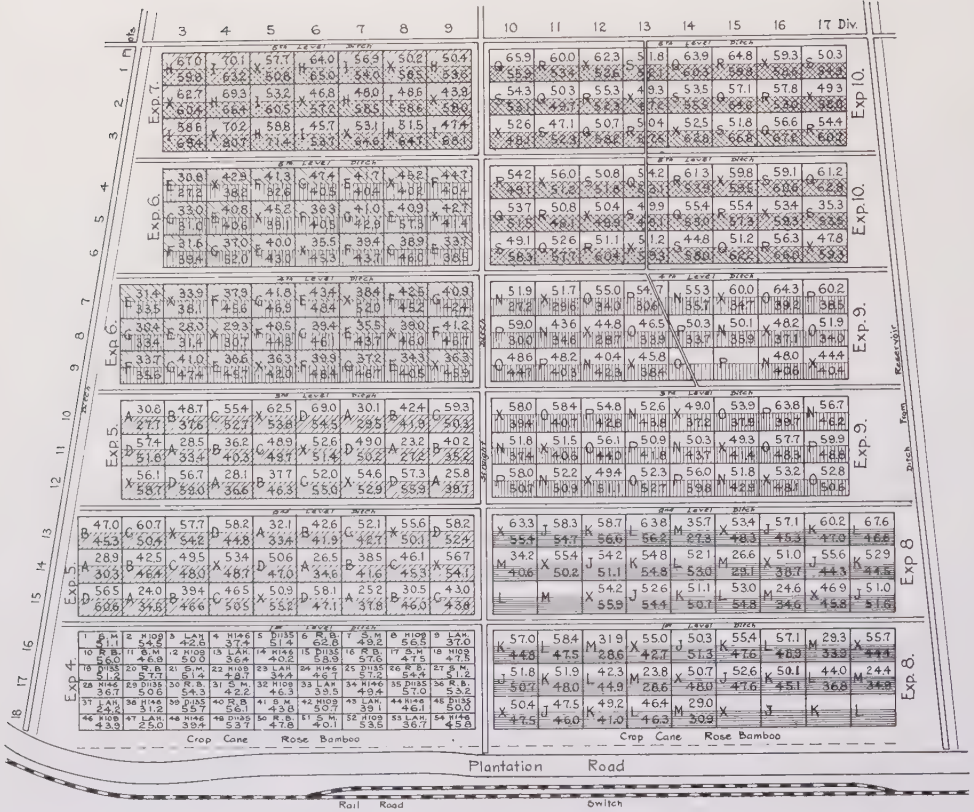
EXP. 7. PHOSPHORIC ACID TEST.

EXP. 8. PLANT FOOD REQUIREMENTS.

EXP. 9. TIME & NUMBER OF APPLICATIONS.

EXP. 10. FORMS OF NITROGEN

Maui Agricultural Co. Expts. 4, 5, 6, 7, 8, 9 & 10, 1923 crop



Key:— = H109. = Lahaina. = Striped Mexican.
 = D1135. = H146. = Rose Bamboo

Experiment No. 4—Varieties of Cane.

In experiment 4, Lahaina, H 146, H 109, Striped Mexican, Rose Bamboo, and D 1135 were compared with the following results:

Variety	Yield per Acre		
	Cane	Q. R.	Sugar
Rose Bamboo	55.5	8.83	6.29
H 109	50.2	8.02	6.26
D 1135	54.0	8.64	6.25
Striped Mexican	47.0	8.43	5.58
H 146	41.4	9.53	4.35
Lahaina	35.0	9.26	3.78

Of the above varieties Rose Bamboo germinated the best, and had a faster start, with D 1135 next best, followed by H 109. H 146 was very slow coming up. Rose Bamboo needed no replanting; in all the others some replanting was necessary.

Rose Bamboo, H 109 and D 1135 were of equal value as sugar producers under the conditions which pertained. Both Lahaina and H 146 gave poor results, due mainly to Root-rot. It should be remembered that H 146 is susceptible to Lahaina disease and should never be planted in fields where this disease is known to be present.

The poor juices from the H 146 and the Lahaina were due, in the main, to diseased and dead cane.

This experiment is being continued as short ratoons.

All the varieties have ratooned well except Lahaina and H 146, which will need replanting.

Details of Experiment.

Object:

To compare the following varieties for conditions existing at the southern end of the plantation: Lahaina, Striped Mexican, D 1135, H 109, H 146 and Rose Bamboo.

Location:

Keahua Section, field 83.

Crop:

Six varieties as plant cane. Planted September 1919; harvested January 1922.

Layout:

Number of plots: 54.

Size of plots: 1/20 acre (31.5'x 69'), composed of 7 straight lines, two watercourses long, or 14 single lines, 4.5'x 34.5'.

Plan:

Plots	No. of Plots	November 1919			Feb. 1920	April. 1920	Total Pounds per Acre		
		N.	P ₂ O ₅	K ₂ O	N.	N.	N.	P ₂ O ₅	K ₂ O
Lahaina	9	58.3	100	60	58.3	58.3	175	100	60
Striped Mexican.	9	58.3	100	60	58.3	58.3	175	100	60
D 1135	9	58.3	100	60	58.3	58.3	175	100	60
H 109	9	58.3	100	60	58.3	58.3	175	100	60
H 146	9	58.3	100	60	58.3	58.3	175	100	60
Rose Bamboo ...	9	58.3	100	60	58.3	58.3	175	100	60

N. from 17½% nitrogen mixture—half nitrate of soda, half sulf. amm.

P₂O₅ from acid phosphate, 16% P₂O₅.

K₂O from sulfate of potash=48% K₂O.

EXPERIMENT NO. 5—HOW MUCH NITROGEN TO USE.

In this test the amounts of nitrogen used varied from nothing to 225 pounds per acre. All plots received phosphoric acid and potash in equal amounts, that is, 625 pounds of acid phosphate and 125 pounds of sulphate of potash per acre.

The amounts of nitrogen used and the results obtained are shown as follows:

Variety	Nitrogen— Pounds per Acre	Tons per Acre		
		Cane	Q. R.	Sugar
H 109	No nitrogen	33.2	8.39	3.95
D 1135	“ “	27.6	9.39	2.94
H 109	75 pounds nitrogen ...	44.0	8.76	5.03
D 1135	75 “ “ ...	40.5	9.32	4.35
H 109	125 “ “ ...	48.8	8.69	5.62
D 1135	125 “ “ ...	51.3	9.40	5.46
H 109	175 “ “ ...	53.2	8.42	6.32
D 1135	175 “ “ ...	55.6	9.00	6.17
H 109	225 “ “ ...	52.3	8.81	5.94
D 1135	225 “ “ ...	57.1	9.24	6.18

The nitrogen produced profitable gains up to a limit of 175 pounds per acre, equal to the use of 1,100 pounds of nitrate of soda. Further additions of nitrogen above this amount did not pay.

It is well to remember that this field suffered severely from lack of water during the summer of 1920. With normal water it is possible that larger amounts of fertilizer could have been used to advantage.

But it is apropos to remark here that heavy fertilization should be done carefully. Fields which are likely to suffer from lack of water cannot be expected to show big profits from heavy fertilization. It is also extremely important not to apply big doses of nitrogen late during the second season, as in that case the juices are likely to be poor and although the cane yields may be high, the sugar “in-the-bag” may prove to be disappointing.

At Waipio, where we now use 300 pounds of nitrogen per acre, we make it an invariable rule to have all fertilizing done at least twelve months before the field is to be harvested. By following this routine we have found that by harvest time the stimulating action of the nitrogen has stopped and that we are able properly to mature the cane. We are harvesting at present cane running above 100 tons to the acre with quality ratio about eight. Had this cane been fertilized late last year, instead of February, the quality ratio, we have reason to know, would be nine or ten.

As a result of our work at Waipio and of our field experiments on the other islands, we are convinced that late fertilization is more detrimental to juices than is heavy fertilization when done at the proper time.

Details of Experiment.

Object:

To determine the most profitable amount of nitrogen for the Keahua lands.

Location:

Field 83, Keahua Section.

Crop:

D 1135 and H 109 plant cane, planted September 1919; harvested January 1922.

Layout:

Number of plots = 51.

Size of plots: 1/10 acre (63'x 69'), composed of 14 lines, two watercourses long, or 28 single lines, 4.5'x 34.5'. Each plot contains D 1135 and H 109, and each variety occupies 7 lines two watercourses long.

Plan:**Fertilization in Pounds per Acre per Application.**

Plot	No. of Plots	November 1919			Feb. 1920	April 1920	Total Pounds per Acre		
		N.	P ₂ O ₅	K ₂ O	N.	N.	N.	P ₂ O ₅	K ₂ O
A	11	....	100	60	....	....	...	100	60
B	11	25	100	60	25	25	25	100	60
C	10	41.6	100	60	41.6	41.6	125	100	60
X	9	58.3	100	60	58.3	58.3	175	100	60
D	10	75	100	60	75	75	225	100	60

N.=Nitrogen from 17½% nitrogen mixture, half nit. soda, half sulf. amm.

P₂O₅=Phosphoric acid from acid phosphate=16% N.

K₂O=Potash from sulfate of potash=48% K₂O.

EXPERIMENT NO. 6—PROPORTION OF NITROGEN TO APPLY EACH SEASON.

In this experiment we applied 175 pounds of nitrogen per acre to all plots, but it was applied at different times to the different plots. All plots also received 625 pounds of acid phosphate and 125 pounds of sulphate of potash per acre.

Both Lahaina and D 1135 in this area suffered to some extent from Root-rot. Cane suffering from this disease responds but little to fertilization. For this reason the results obtained from this test are not to be accepted as in any way conclusive. They are reported here to complete the record.

The results of the harvest are as follows:

Variety	Treatment	Tons per Acre		
		Cane	Q. R.	Sugar
H 146	All nitrogen applied 2nd season, Feb. and April.	40.8	9.73	4.20
Lahaina ...	All nitrogen applied 2nd season, Feb. and April.	36.4	9.81	3.71
H 146	All nitrogen applied 1st season, in November ...	43.2	9.56	4.52
Lahaina ...	All nitrogen applied 1st season, in November ...	38.9	9.97	3.90
H 146	One-third in Nov., two-thirds in Feb. and April.	41.7	9.92	4.21
Lahaina ...	One-third in Nov., two-thirds in Feb. and April.	38.2	10.13	3.77
H 146	Two-thirds in Nov., one-third in Feb. and April.	42.0	9.61	4.37
Lahaina ...	Two-thirds in Nov., one-third in Feb. and April.	39.0	10.27	3.80

The differences here are not very great, but indicate a preference for the early applications of fertilizer.

Details of Experiment.

Object:

To determine what proportion of the fertilizer to apply each season.

Location:

Field 83, Keahua Section.

Crop:

H 146 and Lahaina plant cane, planted September 1919; harvested January 1922.

Layout:

Number of plots: 45.

Size of plots: 1/10 acre (composed of 14 straight lines) two watercourses long, or 28 single 4.5' x 34.5'. Each plot contains two varieties and each variety occupies 7 lines two watercourses long.

Plan:

Proportion of Fertilizer per Season and Application.

Plots	No. of Plots	1st Season	Second Season		Total Pounds		
		Nov. '19	Feb. '20	Apr. '20			
		N.	N.	N.	N.	P ₂ O ₅	K ₂ O
E	12	...	1/2	1/2	175	100	60
X	11	1/3	1/3	1/3	175	100	60
F	11	2/3	1/6	1/6	175	100	60
G	11	All	...	...	175	100	60

All plots are to receive in the first fertilization 100 pounds P₂O₅ from acid phosphate and 60 pounds K₂O from sulfate of potash.

Nitrogen to be applied as 17½% N. mixture, half nitrate of soda, half sulfate of ammonia.

EXPERIMENT NO. 7—PHOSPHORIC ACID.

In this area we compared varying amounts of phosphoric acid, ranging from 50 to 150 pounds of P₂O₅ per acre. All plots received nitrogen at the rate of 175 pounds per acre and 60 pounds of potash.

The results obtained are given in the following table:

SUMMARY OF YIELDS.

Variety	Treatment—				Tons per Acre		
	Pounds per Acre				Cane	Q. R.	Sugar
H 109	312	pounds	acid	phosphate ..	58.4	8.45	6.91
Striped Mexican..	312	"	"	" ..	62.8	8.71	7.21
H 109	625	"	"	" ..	54.9	8.80	6.24
Striped Mexican..	625	"	"	" ..	61.5	9.23	6.66
H 109	937	"	"	" ..	54.1	8.89	6.09
Striped Mexican..	937	"	"	" ..	61.1	9.04	6.76

Increasing the phosphoric acid above 50 pounds per acre was of no value; in fact, the yields were lower. These results are confirmed by those from experiment 8, where there was no appreciable response from phosphoric acid.

An analysis of the soil in this field showed:

Citrate soluble $P_2O_5 = .0095\%$

This soil is, therefore, well supplied with phosphoric acid and will be for some years to come.

Details of Experiment.

Object:

To determine the amount of phosphoric acid to apply under these conditions.

Location:

Field 83, Keahua Section.

Crop:

H 109 and Striped Mexican plant cane, planted September 1919; harvested January 1922.

Layout:

Number of plots 21.

Size of plots: 1/10 acre (63'x 69'), composed of 14 straight lines two watercourses long, or 28 single lines 4.5'x 34.5'. Each plot contains two varieties and each variety occupies 7 lines two watercourses long.

Plan:

Plots	No. of Plots	November 1919			Feb. 1920	April 1920	Total Pounds per Acre		
		N.	P_2O_5	K_2O	N.	N.	N.	P_2O_5	K_2O
H	7	58.3	50	60	58.3	58.3	175	50	60
X	7	58.3	100	60	58.3	58.3	175	109	60
I	7	58.3	150	60	58.3	58.3	175	150	60

N. from 17½% nitrogen mixture, half Nit. Soda, half Sulf. Amm.

P_2O_5 acid phosphate = 16% P_2O_5 .

K_2O sulfate of potash = 48% K_2O .

EXPERIMENT NO. 8—NITROGEN, PHOSPHORIC ACID AND POTASH.

We here tried different combinations of the three main plant foods, nitrogen, phosphoric acid and potash. The nitrogen was kept constant at 175 pounds per acre, except in one series of plots where no nitrogen was used. The results from the different treatments are summarized on the next page:

SUMMARY OF TREATMENTS AND YIELDS.

Variety	Treatment	Tons per Acre		
		Cane	Q. R.	Sugar
Rose Bamboo	Nitrogen only	48.3	8.67	5.57
D 1135	Nitrogen only	53.9	9.29	5.80
Rose Bamboo	Nitrogen and phosphoric acid	49.7	8.72	5.70
D 1135	Nitrogen and phosphoric acid	53.1	8.94	5.94
Rose Bamboo	Nitrogen and potash	48.0	8.92	5.38
D 1135	Nitrogen and potash	54.1	9.06	5.97
Rose Bamboo	Nitrogen, phosphoric acid and potash.	47.7	8.80	5.42
D 1135	Nitrogen, phosphoric acid and potash.	53.6	8.63	6.21
Rose Bamboo	Phosphoric acid and potash	32.1	9.29	3.45
D 1135	Phosphoric acid and potash	29.4	9.32	3.15

The response to 175 pounds of nitrogen amounted to over two tons of sugar per acre. Neither phosphoric acid nor potash, alone or together, produced any profitable gains.

A soil analysis from this field showed the soil to be well supplied with both of these plant foods. The amounts found were as follows:

Citrate soluble $P_2O_5 = .0095\%$

Total acid soluble potash = .394%

As a result of soil studies in connection with our field experiments we do not expect any response from phosphate or potash fertilization from soils such as the above.

In times of low sugar prices, when careful economies are in order, in fields such as the above, it would seem best to use nitrogen only for a limited series of years or crops. Of course this cannot be carried on indefinitely, as the time will come when these soils will need phosphoric acid and potash.

*Details of Experiment.***Object:**

To determine which of the three main plant foods, nitrogen, phosphoric acid and potash, is lacking.

Crop:

D 1135 and Rose Bamboo, planted September 1919; harvested in January 1922.

Location:

Maui Agricultural Co., Keahua Section, field 83.

Layout:

Fifty-four plots, each 1/16 acre (63'x69'), composed of 14 lines two watercourses long. Each plot contains two varieties and each variety occupies 7 lines two watercourses long.

Plan:

Fertilization in Pounds per Acre.

Plot	No. of Plots	November 1919			Feb. 1920	April 1920	Total		
		N.	P ₂ O ₅	K ₂ O	N.	N.	N.	P ₂ O ₅	K ₂ O
X	11	58.3	100	60	58.3	58.3	175	100	60
J	11	58.3	100	..	58.3	58.3	175	100	..
K	11	58.3	...	60	58.3	58.3	175	...	60
L	11	58.3	...	..	58.3	58.3	175	...	..
M	10	....	100	60	....	....	...	100	60

N.=Nitrogen, half nit. soda, half amm. sulf.

P₂O₅=Phos. acid from acid phosphate, 16% P₂O₅.K₂O=Potash from sulf. of potash, 48% K₂O.

EXPERIMENT NO. 9—NUMBER OF APPLICATIONS OF FERTILIZER.

In this test we tried applying a given amount of fertilizer in two, three and four applications. All plots received complete fertilizer, at the rate of 175 pounds of nitrogen, 100 pounds of P₂O₅ and 60 pounds of K₂O per acre.

The results obtained are tabulated as follows:

Variety	Treatment	Tons per Acre		
		Cane	Q. R.	Sugar
H 146	Two applications	40.8	9.10	4.51
D 1135 ...	Two applications	53.2	8.99	5.97
H 146	Three applications ..	38.9	9.22	4.22
D 1135 ...	Three applications ...	50.4	10.01	5.04
H 146	Four applications	41.8	9.57	4.37
D 1135 ...	Four applications	54.3	9.64	5.63

From the above we see that the best results were obtained when all the fertilizer was applied in two doses rather than in three or four. This is in complete accordance with our results elsewhere.

The main advantage to the application of fertilizer in few doses rather than many lies in the fact that the fertilization is finished earlier during the second season, and better juices are obtained.

*Details of Experiment.***Object:**

To determine the best time and number of applications in which to apply a given amount of fertilizer.

Location:

Field 83, Keahua Section.

Crop:

H 146 and D 1135 plant cane, planted September 1919; harvested January 1922.

Layot:

Number of plots: 44.

Size of plots: 1/10 acre (63'x 69'), composed of 14 straight lines each two watercourses long, or 28 single lines 4.5'x 34.5'. Each plot contains two varieties and each variety occupies 7 lines two watercourses long.

Plan:

Plot	No. of Plots	November, 1919			Feb., 1920	April, 1920	June, 1920	Total Pounds per Acre		
		N.	P ₂ O ₅	K ₂ O	N.	N.	N.	N.	P ₂ O ₅	K ₂ O
N	12	58.3	100	60	116.6	....	....	175	100	60
X	12	58.3	100	60	58.3	58.3	....	175	100	60
O	12	58.3	100	60	38.8	38.8	38.8	175	100	60
P	12	58.3	100	60	....	116.6	....	175	100	60

N. from 17½% nitrogen mixture, half nit. soda, half sulf. ammonia.

P₂O₅ from acid phosphate 16% P₂O₅.

K₂O from sulfate of potash = 48% K₂O.

EXPERIMENT NO. 10—FORMS OF NITROGEN.

Equal amounts of nitrogen from various sources were compared in this test. The results obtained are summarized below:

Variety	Treatment	Tons per Acre		
		Cane	Q. R.	Sugar
Striped Mexican..	Nitrate of soda	58.0	9.61	6.04
D 1135	Nitrate of soda	56.1	9.52	5.89
Striped Mexican..	Sulf. of ammo.....	56.0	9.26	6.04
D 1135	Sulf. of ammo.....	56.0	9.74	5.75
Striped Mexican..	Half nitrate of soda, half sulf. of ammo.	55.0	9.02	6.10
D 1135	Half nitrate of soda, half sulf. of ammo.	53.6	9.51	5.64
Striped Mexican..	Dried blood	55.5	9.33	5.94
D 1135	Dried blood	49.8	9.22	5.40

The yields obtained were practically identical for all treatments, except that nitrogen from organic sources was not quite as good, and was the most expensive per unit.

The above is in line with results obtained at other places. The best returns are obtained where the nitrogen is in quickly available form. This holds good for the wet districts as well as the dry ones.

*Details of Experiment.***Object:**

To compare the value of nitrogen as: (1) Nitrate of Soda, (2) Sulfate of Ammonia, (3) Mixture of Nitrate and Sulfate, (4) Dried Blood.

Location:

Field 83, Keahua Section.

Crop:

D 1135 and Striped Mexican plant cane, planted September, 1919; harvested January, 1922.

Layout:

Number of plots: 48.

Size of plots: 1/10 acre (63'x 69'), composed of 14 straight lines two watercourses long, or 28 single lines 4.5'x 34.5'. Each plot contains two varieties and each variety occupies 7 lines two watercourses long.

Plan:

Plot	No. of Plots	Form Nit.	November, 1919			Feb., 1920	April, 1920	Total Pounds		
			N.	P ₂ O ₅	K ₂ O	N.	N.	N.	P ₂ O ₅	K ₂ O
Q	12	N. S.	58.3	100	60	58.3	58.3	175	100	60
R	12	S. A.	58.3	100	60	58.3	58.3	175	100	60
X	12	{ Nit.	58.3	100	60	58.3	58.3	175	100	60
		{ Sul.								
S	12	{ Mix.	58.3	100	60	58.3	58.3	175	100	60
		{ Dried Blood								

N. S. = 15.5% N.

S. A. = 20.5% N.

Nit. Sulf. Mix. = 17½% N. (half N. S., half S. A.).

Blood = 12% N.

The Soil Solution by Displacement.

By W. T. McGEORGE.

There has recently appeared in *Soil Science* an article by F. W. Parker of the Wisconsin Experiment Station dealing with the different methods of studying the soil solution.

He divides the methods which have been used into three classes as follows:

- (a) Methods involving extraction with comparatively large amounts of water,
- (b) methods which aim to measure the concentration of the soil solution directly in the soil, and
- (c) methods which aim to obtain the true soil solution.

The advantages possessed by the water extraction method have caused its extensive adoption as a method of studying the soil solution as well as the more available plant food. Its limitations are admitted, however, and the results obtained thereby represent the partial solvent action of water, rather than the actual soil solution. The comparative value of such data is further limited by the numerous physical and chemical factors which govern the concentration of the organic and inorganic constituents in the water extract, so that the same ratio of water to soils will not yield directly comparable extracts on all types. A ratio of one part soil to five parts water is the most widely adopted procedure, and while this ratio is more or less arbitrary it has been applied extensively to local soils.

Under the methods of measuring the concentration of the soil solution directly in the soil, attention is called to the determination of the freezing point of the soil solution and its electrical conductivity. These methods are, however, limited to the concentration and will not lead to information regarding the composition.

Methods of isolating the soil solution, itself, may be classified as follows: Centrifugal, pressure, and displacement methods. Centrifugal methods have yielded only small amounts of soil solution even in soils of high moisture content. Pressure methods, while they have been applied successfully by several investigators, require a rather complicated apparatus and yield only from soils of high moisture content. This method was tried out on Hawaiian soils by P. S. Burgess, but since there is no record of his results it is assumed that it was not adapted. While the displacement of the soil solution is not a recent idea, its practical application has apparently been revived by Mr. Parker, who has applied it with excellent results on Wisconsin soils. Its simplicity is a strong factor in its application.

In our studies on Hawaiian soils it is justifiable to assume that any method which would throw some light upon the composition of the soil solution, on which, after all, the plant is dependent for its mineral plant food supply, would be of no small value. Previous work has shown the numerous variations or fluctuations of the soil solution due to seasonal changes, fertilization, rainfall, crop growth

and biological activities. These will govern the limitations of the method as a means of determining plant food deficiencies, but it should be ideally adapted for studying soil changes. The desirability of a reliable method for determining the concentration, composition, mineral ratio, and other factors, which a knowledge thus obtained would give us, is apparent. Some time has therefore been devoted to a study of the displacement method developed by Mr. Parker as applied to Hawaiian soils.

The method consists in packing the soil in a glass cylinder or percolator. The displacing liquid is then poured on top of the soil column and as it penetrates the soil it displaces some of the soil solution which forms a zone of saturation below the displacing liquid. This is gradually forced downward until finally the soil solution drops from the soil as gravitational water.

The only apparatus required is a glass cylinder in which to pack the soil, its size depending upon the amount of soil it is desired to work or the volume of soil solution sought. In our work, glass cylinders (2" diameter) holding 800 grams of soil and glass percolators ($3\frac{1}{4}" \times 16\frac{1}{2}"$) holding 3000 grams of soil were used.

Mr. Parker compared the displacing value of several liquids, of which ethyl alcohol proved best adapted. It was therefore adopted without further study as a displacing liquid in this work.

METHOD OF PROCEDURE.

We have in the nitrates a soil component, which for all practical purposes may be accurately determined by extracting the soil with water. It is therefore evident that any method of separating the soil solution from the soil particles should yield a solution the nitrate content of which is comparable, when reduced to an equal basis, with that determined by extraction. Hence the nitrate determination was adopted as a means of checking the true soil solution.

In packing the soils it was found to be very essential that a uniform pack be obtained. This may be accomplished by carefully and continually tamping with a wooden rod ($\frac{3}{4}"$ diameter) while the soil is being slowly poured into the cylinder. A little experience may be necessary to judge the degree of firmness which allows best percolation. This is governed by moisture content and physical texture. In the more sandy types there is no danger of puddling, but in the clay and silty loams the highest moisture content at which the soil may be squeezed in the hand without puddling seems best adapted to the conditions of the experiment, although a slightly lower moisture content permitted more rapid percolation.

The time required for complete displacement varied from three hours in a sandy loam to approximately one week in a heavy clay. The time of displacement in the clays was decreased to as little as twenty-four hours by working at lower moisture content. The solution obtained requires no filtration, being perfectly clear, clouding rapidly, however, on standing, due to absorption of carbon dioxide from the air.

Eleven soils, representing a wide range of Island types, were used in this work. Total soluble solids was obtained by evaporating 50 cc. of the soil solu-

tion to dryness in a platinum dish and nitrates coloremometrically by the phenol-disulphonic acid method, using 10 cc. of the soil solution.

Results are given in the following table and are calculated to parts per million solids and nitrates in the moisture free soil. Moisture content of the soil is also given to show the amount present in the soil as used.

TABLE I.

TABLE SHOWING VARIATION IN CONCENTRATION OF SOIL SOLUTION AND COMPARING NITRATES BY DISPLACEMENT AND EXTRACTION.

Soil	Total solids p. p. mil water free soil	Nitrates p. p. mil by displace- ment	Nitrates p. p. mil by extraction	Per cent moisture in soil
1. Maui Agri. (red clay).....	150	8.5	8.7	20.0
2. Oahu Field 45 (red clay).....	184	7.9	8.1	24.4
3. Pioneer (red clay).....	75	4.0	3.9	22.4
4. Station soil (brown silt).....	157	5.2	4.9	20.0
5. Hakalau (yellow clay).....	249	1.3	3.9	45.6
6. Onomea (yellow clay).....	337	Trace	8.1	36.8
7. Hilo Sugar (yellow clay).....	200	3.6	6.6	44.4
8. Hilo Sugar (yellow clay).....	322	3.5	6.5	43.8
9. Honolulu Plant. (red clay).....	593	21.6	26.5	28.0
10. Waialua (red silt).....	421	25.1	31.7	31.0
11. Honokaa (silty sand).....	169	15.7	14.6	31.0

The results, with the exception of soils numbers 5 to 8 inclusive, as judged by the nitrate content, indicate the true soil solution to have been obtained. The exceptions are of the yellow clay type which predominates in the Hamakua coast district on Hawaii, possessing high moisture content and high degree of hydration. Two possible explanations of the results obtained suggested themselves. Either the true soil solution was not obtained in these soils or nitrates were lost during displacement by denitrification.

Since these soils were packed very tightly and percolation was extremely slow, loss of nitrate appeared the most plausible explanation. In order to test this out, nitrate determinations were made at different depths in soil number 7 as taken from the glass cylinder about one week after displacement had been completed. The top layer, dried out, showed a faint trace of nitrate, probably from subsequent nitrification, while no nitrate was present in the lower depths, indicating that the nitrates had entirely disappeared during the displacement.

In order further to prove this, three soils, a sandy loam, a silty loam, and a clay loam, all high in nitrates, were packed in percolators and alcohol was poured on top of the soil. Nitrate determinations were made on the first portions of the displaced solution and the last portion preceding that in which alcohol contamination was apparent. In the sandy soil, displacement was complete in three hours, 300 cc. from 2000 grams or 49% being obtained. Both the first and last portions checked exactly, 15.7 parts per million nitrogen as nitrate. However, this soil solution, on standing in a tightly corked flask two days, decreased in

nitrate nitrogen from 15.7 to 8.5 parts per million. The other two soils percolated more sluggishly, the silty loam yielding 250 cc. in two days and the clay loam 150 cc in two days. The analysis of the first and last portions as above showed the former to have dropped from 25.1 p. p. m. in the first portion to 0.94 p. p. m. in the last, while the clay dropped from 26.5 to 0.19 p. p. m.

These results clearly prove the discrepancies in Table I to be due to denitrification, and indicate that where the nitrate determination is used as a check, determinations should be made only on the first portions of the displaced solution in all cases where displacement is sluggish.

In view of these promising results the work was further extended to compare results obtained by the water extraction methods and the soil solution by displacement. Extractions were made using ratios of 1:1, 2:5, and 1:5 parts soil to water. Soil and water of the above proportions were shaken for three hours in a shaking machine, filtered through Pasteur tubes and total solids determined by evaporating 50 cc. of the filtrate to dryness on the steam bath. The results are given in Table II, calculated to and comparing p. p. m. water free soil and in the solution obtained. It will be noted that there is considerable variation, but in most cases an extraction ratio of 1:1 dissolves amounts of solids closely related to that of the soil solution if both are calculated in terms of water free soil. This does not apply universally, for the reason that extraction methods, regardless of solvent, will vary on the different soil types, depending upon certain chemical and physical influences.

TABLE II.
COMPARING EXTRACTION AND DISPLACEMENT.

Soil	(P. p. mil. water free soil)				(P. p. mil. in solution)				H ₂ O in Soil
	1 : 1	2 : 5	1 : 5	Disp.	1 : 1	2 : 5	1 : 5	Disp.	
Oahu Field 45	194	100	92	572	211	298	639	184	24.4
Pioneer	104	80	48	300	113	235	323	75	22.4
Station soil	154	119	94	630	160	342	611	157	20.0
Hakalau	166	136	128	298	199	481	1292	249	45.6
Onomea	142	100	64	580	163	229	544	337	36.8
Hilo Sugar	198	152	90	350	237	532	884	200	44.4
Hilo Sugar	142	94	68	254	170	327	679	322	43.8
Honolulu Plantation ..	488	274	232	1524	547	842	1702	593	28.0
Waialua	286	170	82	936	324	535	681	421	31.0
Honokaa	160	90	60	376	181	283	461	169	31.0

DISCUSSION AND VALUE OF METHOD.

These results, it is believed, prove that the displacement method, using ethyl alcohol as the displacing liquid, gives the true soil solution with Hawaiian soils. It can be used at a wide range of moisture content, and in those cases in which data were collected to show the per cent recovery a variation of 16 to 60 per cent of the water present in the soil was recovered. The maximum recovery

is possible in all cases in which careful note of and allowance for moisture is made. The puddled condition resulting from working soils of too high moisture content was in extreme cases found to prohibit displacement entirely.

The data in Table I indicate a wide variation in the concentration and composition of the soil solution in Hawaiian soils. Apparently lime is an important factor, as the highest concentration is noted in the high lime and the lowest in the low lime soils.

Further data are submitted in Table III, showing the variation in lime, potash and phosphoric acid in seven soils and three subsoils. The results are expressed in parts per million in water free soil and are submitted simply to illustrate variations. Comment must necessarily be reserved for further accumulation of data. However, attention is called to the low phosphoric acid figures and the high potash results obtained on the high lime soils.

TABLE III.

SHOWING CaO , K_2O AND P_2O_5 IN DISPLACED SOIL SOLUTION CALCULATED P. P. MIL. H_2O FREE SOIL.

	Lime CaO	Potash K_2O	Phosphoric Acid P_2O_5
Waimanalo soil	35.6	23.2	.6
Waimanalo subsoil	28.2	16.3	Trace
Waimanalo soil	11.9	9.5	1.3
Waimanalo subsoil	6.9	2.3	Trace
Waimanalo soil	38.9	4.1	Not det.
Oahu soil	24.3	16.5	.9
Honokaa subsoil	12.1	10.8	Trace
Honolulu Plantation soil	62.3	19.0	3.3
Waialua soil	41.0	22.9	.3
Hakalau soil	54.1	21.0	Not det.

We know that the soil solution is saturated only with respect to the particular system existing at any given time, that it is constantly undergoing modifications of sufficient proportions to require an examination of the soil solution at frequent intervals in order to derive complete value from the analyses. The wide variation in concentration, however, to be noted in Tables I and III, indicate a possible value as a means of ascertaining in a limited way plant food deficiencies in our soils. An extensive comparison of the soil solution from good and poor fields would be necessary to answer this.

Its principal value appears to lie in its adaptation to studying soils in which toxic constituents are suspected and those in which a knowledge of the changes in plant food due to plant growth, fertilization, rainfall, irrigation, etc., is desired. In order to illustrate, a series of samples taken from Experiment 6, Oahu Sugar Co., field 45 (an upland red clay soil), were treated by the displacement method given above. In this experiment all plots have received the same potash and nitrogen application—namely, 60 pounds potash from muriate and 150 pounds

TABLE IV.
COMPARING CONCENTRATION OF SOIL SOLUTION FROM EXPERIMENT 6, OAHU SUGAR CO.

	X Plots			A Plots			B Plots			C Plots		
Moisture in soil	24.6	24.0	25.2	24.0	23.2	24.2	23.8	24.2	22.8	24.6	22.6	23.4
Parts per million solids in soil solution.	358	358	350	430	361	446	458	444	400	360	418	386
Average	355			424			405			395		

TABLE V.
SHOWING LIME, POTASH AND TOTAL SOLIDS IN PARTS PER MILLION
WATER FREE SOIL.

	X Plots	A Plots	B Plots	C Plots
Lime (CaO)	6.65	12.06	8.82	7.78
Potash (K ₂ O)	11.3	7.95	8.11	8.55
Total Solids	113.9	133.5	127.7	124.4

nitrogen from sodium nitrate per acre. In addition the X plots received no phosphoric acid, the A plots 180 pounds phosphoric acid per acre from reverted phosphate, the B plots 90 pounds from reverted phosphate, and the C plots 90 pounds from acid phosphate. Fertilizer was applied in February, 1921, with an additional dose of nitrogen only in May, 1921. The soil samples were taken in December, 1921, ten months after the application of the fertilizer. The cane was approximately one year old from second ratoons. All plots were thoroughly sampled in order to obtain a representative sample. The analyses are given in Tables IV and V, the total solids being determined separately as shown in Table IV, and the soil solutions from similar plots combined for the determination of potash and lime.

The data presented here are very concordant and illustrate very clearly the value of the method for studying fertilizer applications. There is practically no difference in the moisture content of the samples from the sixteen plots, a very fortunate circumstance in comparing the concentration of the soil solution as obtained from this series. Variation in total solids agrees very closely with fertilizer applications. The lime in solution is as would be anticipated, also. The phosphate results showed a very low concentration, only a trace being indicated in the colorimetric determination. All plots received the same potash application and the higher concentration in the X plots may be due to the poorer growth made in the plots to which no phosphoric acid was applied with the accompanying lower drain on the soluble plant food.

In applying the method to a comparison of the relative concentration of the soil and subsoil solutions, three soils with their respective subsoils were treated with alcohol as above and the determinations given in the following table were made.

TABLE VI.
SHOWING TOTAL SOLIDS AND LIME IN SOIL AND SUBSOIL SOLUTION,
P. P. M. WATER FREE SOIL.

	Water in Soil	Total Solids	Lime CaO
1. Brown clay soil.....	20.0%	133	11.9
1. Brown clay subsoil.....	25.0%	65	6.9
2. Dark greyish clay soil.....	24.0%	262	38.9
2. Dark greyish clay subsoil.....	24.8%	241	39.1
3. Red clay soil.....	21.0%	292	35.6
3. Red clay subsoil.....	29.0%	230	28.2

Little comment on the above is necessary. The results are as would be anticipated in comparing soil and subsoil, namely, a lower concentration in the subsoil solution.

CONCLUSIONS.

1. Using ethyl alcohol as a displacing liquid, the true soil solution may be obtained from Hawaiian soils.
2. In a majority of the soils used, the displacement method gives approximately the same amount of total salts as a 1:1 extraction with distilled water.
3. The method is especially adapted to a study of the composition of the soil solution as influenced by fertilization, plant growth, irrigation, temperature and other factors and for studying variations between good and poor fields.
4. The principal limitation lies in the taking of the soil sample. If the soil at time of sampling is too wet it becomes puddled thereby and its proper packing in cylinders for displacement is impossible. Drying out in the laboratory after bringing from the field is impractical, due to the increase in the solubility of the soil constituents resulting therefrom. It is therefore essential that attention be given to this point.

Nitrogen Gives Results at Lihue.

LIHUE PLANTATION CO.—EXPERIMENT 5, 1922 CROP.

This is an experiment to determine the economic limit in nitrogen application on plant cane at Lihue. It is of unusual significance and importance since beneficial results were obtained here on plant cane on land very similar to neighboring Grove Farm fields, situated at about the same elevations, in which the plant cane did not respond to nitrogen.

These differences in response to nitrogen fertilization are probably due to the fact that Grove Farm fields are pastured and green fallowed for three years between cane crops.

The cane was Yellow Caledonia, planted in April, 1920, and cut back in July.

A uniform dose of 240 pounds of molasses ash per acre was applied to all plots in July, 1920, and a uniform dose of 500 pounds of reverted phosphate was applied to all plots the first of August.

It was originally intended to apply the nitrogen in three equal doses in August, January, and March. It was necessary to change this plan, however, and the first dose was applied in October, 1920, and the other two doses were combined and applied the last of February, 1921.

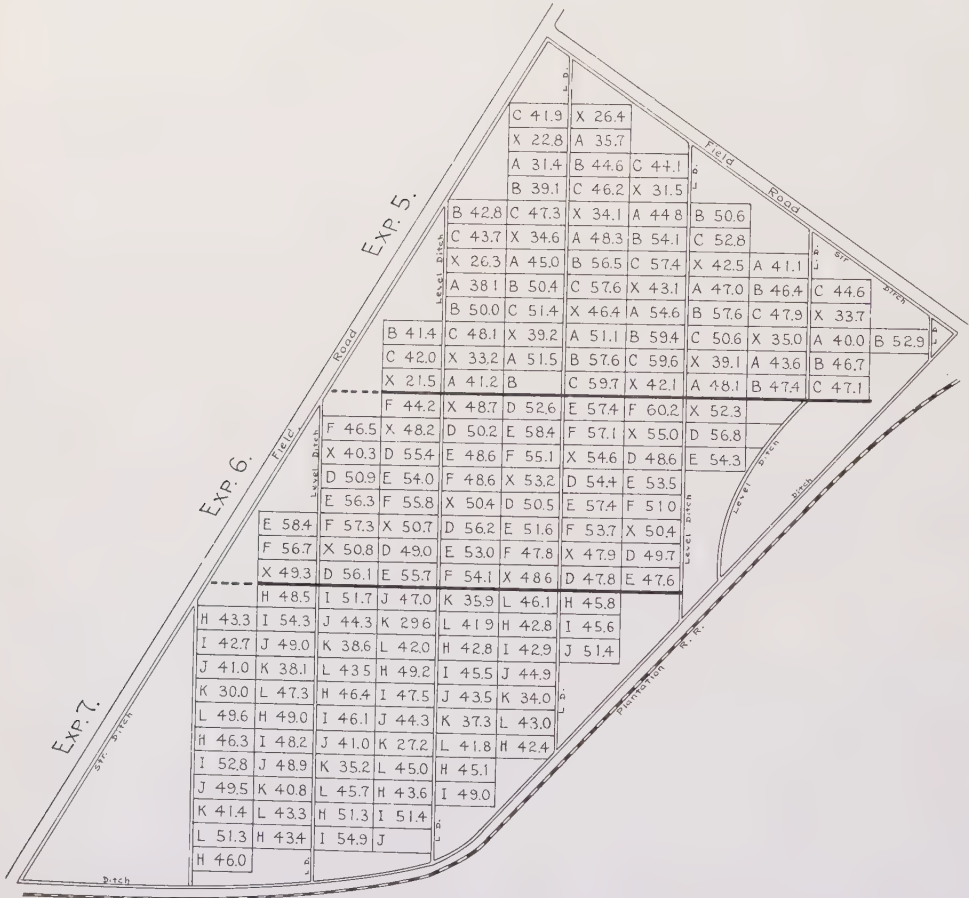
EXP. 5. AMOUNT OF NITROGEN.

EXP. 6. AMOUNT OF PHOSPHORIC ACID.

EXP. 7. PLANT FOOD REQUIREMENTS.

LIHUE PLANTATION Co. EXPTS. 5, 6 & 7, 1922 CROP

FIELD 13.



SUMMARY OF RESULTS

EXP. 5.

Plots	No. of Plots	N.	P ₂ O ₅	K ₂ O	Yields Per Acre			Gain or Loss Over X Plots	
					CANE	G.R.	SUGAR	CANE	SUGAR
X	16	0	70	60	34.44	8.1	4.25		
A	15	75	70	60	44.08	8.0	5.51	+ 9.64	+ 1.26
B	17	150	70	60	49.82	8.6	5.79	+ 15.38	+ 1.54
C	17	225	70	60	49.51	8.7	5.69	+ 15.07	+ 1.44

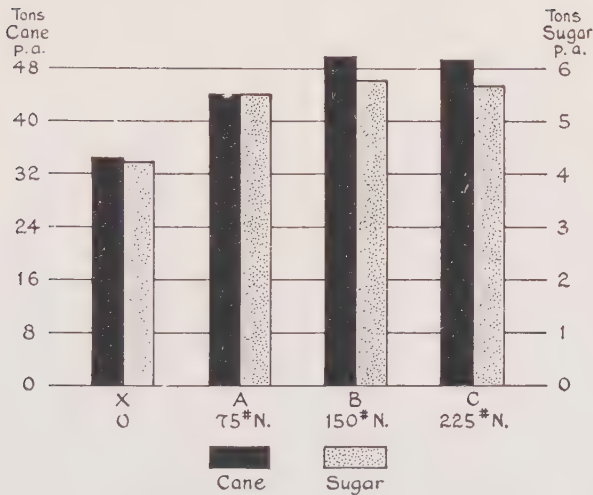
EXP. 6.

Plots	No. of Plots	N.	P ₂ O ₅	K ₂ O	Yields Per Acre			Gain or Loss Over X Plots	
					CANE	G.R.	SUGAR	CANE	SUGAR
X	14	150	0	60	49.99	8.0	6.25		
D	13	150	70	60	52.15	8.2	6.36	+ 2.16	+ 0.11
E	13	150	140	60	54.30	8.5	6.39	+ 4.31	+ 0.14
F	13	150	210	60	52.91	8.5	6.23	+ 2.92	- 0.02

EXP. 7

Plots	No. of Plots	N.	P ₂ O ₅	K ₂ O	Yields Per Acre			Gain or Loss Over H Plots	
					CANE	G.R.	SUGAR	CANE	SUGAR
H	15	150	0	0	45.71	7.8	5.86		
I	13	150	70	0	48.63	7.7	6.32	+ 2.92	+ 0.46
J	12	150	0	60	45.85	7.8	5.88	+ 0.14	+ 0.02
K	11	0	70	60	35.26	7.6	4.64	- 10.45	- 1.22
L	12	150	70	60	45.02	7.8	5.77	- 0.69	- 0.09

AMOUNT OF NITROGEN.
Lihue Plantation Co. Exp. 5, 1922 crop
Plant Cane



In addition to the potash and phosphates applied the amounts of nitrogen applied are given in tabular form as follows:

Nitrate of Soda per Acre.

Plot	No. of 1/10 Acre Plots	October	February	Total Nitrogen
X	16	...	...	...
A	15	161	323	75
B	17	323	646	150
C	17	484	968	225

The harvesting results obtained from this experiment were as follows:

Summary of Results.

Plot	Nitrogen per Acre	Yields per Acre			Gain or Loss Over X Plots	
		Cane	Q. R.	Sugar	Cane	Sugar
X .....	...	34.44	8.1	4.25	....	....
A	75	44.08	8.0	5.51	9.64	1.26
B	150	49.82	8.6	5.79	15.38	1.54
C	225	49.51	8.7	5.69	15.07	1.44

In this experiment there was a decided gain, both in cane and in sugar from 75 pounds of nitrogen. While an additional 75 pounds of nitrogen per acre appreciably increased the amount of cane, the quality of the juice was low-

ered and the resulting increase in sugar was not so marked as with the first 75 pounds. Increasing the nitrogen to 225 pounds gave no further increase in cane, and lowered the quality of the juices slightly.

DETAILS OF EXPERIMENT.

Object:

To determine the economic limit of nitrogen to apply as nitrate of soda under conditions at Lihue Plantation Co.

Location:

Field 13.

Crop:

Yellow Caledonia, plant.

Layout:

Number of plots: 65.

Size of plots: 1/10 acre (40.3'x108'), composed of 24 straight lines one watercourse long.

Rows 4.5' wide and 40.3' long.

Plan:

Fertilization — Pounds per Acre.

Plots	No. of Plots	May, 1920		October, 1920		N. S. Feb.,	Total Nitro.
		R. P.	M. A.	N. S.	N. S.	1921	
X	16	500	240	...	...	...	...
A	15	500	240	161	...	323	75
B	17	500	240	323	...	646	150
C	17	500	240	484	...	968	225

Fertilizer — Nitrate of Soda: 15.5% N.

Experiment planned by J. A. Verret, R. S. Thurston and J. H. Midkiff.

Experiment laid out by R. S. Thurston and J. H. Midkiff.

Experiment fertilized and harvested by J. H. Midkiff.

Chemical analyses by B. Henderson.

J. H. M.

Phosphate Experiment at Lihue.

LIHUE PLANTATION COMPANY — EXPERIMENT 6, 1922 CROP.

This experiment was designed to determine the value of phosphate on land lying through the central part of Lihue Plantation. It is neither in the mauka section of the plantation, where it is generally conceded that phosphates give results, nor in the makai section, where phosphates are generally thought to be unneeded.

The cane was Yellow Caledonia, planted in April 1920, and cut back in July.

A uniform dose of 240 pounds per acre of molasses ash was applied to all the plots in July 1920. All plots received nitrogen in nitrate of soda applied at the rate of 150 pounds of nitrogen, or 968 pounds of nitrate of soda, per acre.

The reverted phosphate was applied in the line to the cane in August, soon after the cane started to send its shoots up after the cutting back.

A summary of the fertilizer applications follows:

Fertilizer per Acre.

Plots	Rev. Phos. August	Molasses Ash	Nitrate of Soda	
			October	February
X .....	....	240	323	646
D	500	240	323	646
E	1,000	240	323	646
F	1,500	240	323	646

The harvesting results obtained from this experiment were as follows:

Plots	No. of Plots	Treatment			Yields per Acre			Gain or Loss Over X Plots	
		P ₂ O ₅	N.	K ₂ O	Cane	Q. R.	Sugar	Cane	Sugar
X	14	...	150	60	49.99	8.0	6.25	.....	.....
D	13	70	150	60	52.15	8.2	6.36	+ 2.16	+ 0.11
E	13	140	150	60	54.30	8.5	6.39	+ 4.31	+ 0.14
F	13	210	150	60	52.91	8.5	6.23	+ 2.92	— 0.02

In this experiment all applications of phosphates gave small increases in cane, although 500 pounds of reverted phosphate gave practically the same increase in cane as 1500 pounds.

While these gains are small, the need for phosphates is shown, and we feel that they should be added. We believe that the phosphate needs of this soil are now taken care of by the P₅O₂ in the high grade fertilizer used, and that no extra applications are called for.

DETAILS OF EXPERIMENT.

Object:

To determine the value of applying reverted phosphate under conditions at Lihue Plantation Co.

Location:

Field 13.

Crop:

Yellow Caledonia, plant.

Layout:

Fifty-three plots, each 1/10 acre (40.3'x108'), composed of 2 4straight lines one watercourse long. Rows 4.5' wide and 40.3' long.

Fertilization — Pounds per Acre.

Plots	No. of Plots	Lbs. of Rev. Phos. Aug., 1920	Aug. M. A.	Oct. N. S.	Feb. N. S.	Total N.
X	14	....	240	323	646	150
D	13	500	240	323	646	150
E	13	1,000	240	323	646	150
F	13	1,500	240	323	646	150

Experiment planned by J. A. Verret, R. S. Thurston and J. H. Midkiff.

Experiment laid out by R. S. Thurston and J. H. Midkiff.

Experiment fertilized and harvested by J. H. Midkiff.

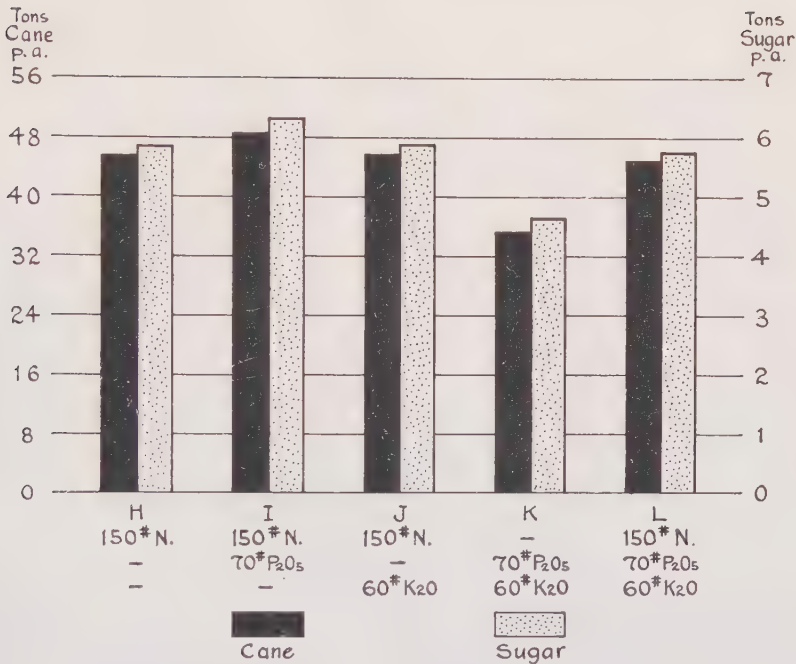
Juice analyses by B. Henderson.

J. H. M.

PLANT FOOD REQUIREMENTS.

Lihue Plantation Co. Exp. 7, 1922 crop

Plant Cane



Plant Food Experiment at Lihue.

LIHUE PLANTATION CO.—EXPERIMENT 7, 1922 CROP.

This is a plant food experiment to determine the value of nitrogen, phosphates and potash. Like Experiment 5 in the same field, it tests the value of nitrogen; like Experiment 6, it deals with phosphates. In addition it checks on the value of potash under these conditions.

The cane is Yellow Caledonia, planted April 1920, cut back in July.

The molasses ashes and the reverted phosphate were applied to the cane soon after it had begun to send out its new shoots after cutting back. The nitrogen was applied in October 1920, and February 1921.

The fertilizer applications are given in tabular form as follows:

Plots	Pounds per Acre			
	July	August	October	February
H .....	.....	.....	323 N. S.	646 N. S.
I .....	.....	500 R. P.	323 N. S.	646 N. S.
J	240 M. A.	.....	323 N. S.	646 N. S.
K	240 M. A.	500 R. P.	.....	.....
L	240 M. A.	500 R. P.	323 N. S.	646 N. S.

The results obtained from harvesting this experiment are as follows:

Plots	Yields per Acre			Gain or Loss Over	Check H Plots
	Cane	Q. R.	Sugar	Cane	Sugar
H	45.71	7.8	5.86	.....	.....
I	48.63	7.7	6.32	+ 2.92	+ 0.46
J	45.85	7.8	5.88	+ 0.14	+ 0.02
K	35.26	7.6	4.64	— 10.45	— 1.22
L	45.02	7.8	5.77	— 0.69	— 0.09

Checking closely with the results of Experiment 5, the addition of 150 pounds of nitrogen gave an increase of approximately one and one-quarter tons of sugar per acre. Like Experiment 6, the addition of 500 pounds of reverted phosphate per acre gave a slight increase in cane. In this experiment the juice was not lowered by the addition of phosphate and nearly half a ton more sugar per acre resulted from the phosphate application. Potash apparently had very little effect in the yield of cane or sugar, the differences in the yields being within the limits of experimental error.

DETAILS OF EXPERIMENT.

Object:

To determine the plant food requirements of sugar cane under condition at Lihue Plantation Company. Comparisons are made between:

1. Nitrogen.
2. Nitrogen and Phosphoric acid.
3. Nitrogen and Potash.
4. Nitrogen, Phosphoric Acid and Potash.
5. Phosphoric Acid and Potash.

Location:

Field 13.

Crop:

Yellow Caledonia, plant.

Layout:

There were 63 plots, each 1/10 acre (40.3'x 108'), composed of 24 straight lines one watercourse long. Rows 4.5' wide and 40.3' long.

Plan:

Fertilization — Pounds per Acre.

Plots	No. of Plots	July, 1920			Jan., 1921	March, 1921	Total Pounds		
		N. S.	R. P.	M. A.	N. S.	N. S.	N.	P ₂ O ₅	K ₂ O
H	15	323	...	...	323	323	150	...	...
I	13	323	500	...	323	323	150	70	...
J	12	323	...	240	323	323	150	...	60
K	11	...	500	240	...	...	...	70	60
L	12	323	500	240	323	323	150	70	60

N. S. = 15.5% N. R. P. = 14% P_2O_5 . M. A. = 25% K_2O .

Experiment planned by J. A. Verret, R. S. Thurston and J. H. Midkiff.

Experiment laid out by R. S. Thurston and J. H. Midkiff.

Experiment fertilized and harvested by J. H. Midkiff.

Analyses of juice samples by B. Henderson.

J. H. M.

Something About Separators.*

By W. H. WAKEMAN.

Three modern high-speed engines were used to supply power for a certain manufacturing plant. They were removed and replaced by three turbines. The sole reason for the exchange was that all exhaust steam was wanted for use in the works, but inasmuch as the exhaust contained more or less cylinder oil on coming from the engines, the turbines were adopted, because they used no cylinder oil.

A dealer claims that he supplied one separator to another plant, with the expectation of furnishing more provided the first removed all cylinder oil from the exhaust steam and the others were delivered in due time. If it was possible to secure this result in one case, why could it not have been done in the other? Changing the prime movers was much more expensive than it would have been to install separators. If there was any difference in the steam consumption, it had no weight in arriving at a decision in this case, because all exhaust steam was used to advantage in manufacturing processes. Several other dealers in separators claim to secure practically the same results. Why are failures along this line frequently found?

One reason is because some cylinder oils are much more viscous than others. As this quality may be defined as "sticky," it means that some kinds excel others in cleaving to the iron surface with which they come in contact, hence if a certain separator does not remove all the oil, a simple and inexpensive experiment may be tried by substituting other brands of oil until better results are secured or the separator is proved to be responsible for the failure.

The chief engineer of a mill found that the exhaust steam from his engine contained oil. The separator was located next to the engine and beyond it, a feed water heater. When the location of these two appliances was changed to that illustrated in Fig. 1, the cylinder oil was removed from the exhaust steam, and this was the only change made. The philosophy of the operation and succeeding practice is that when cold water was pumped into the heater and a portion of the steam condensed in the process of heating the water, the resulting drops of water combined with the particles of oil, and as the mixture became heavier than the steam, it was readily separated from it by centrifugal force; hence, the better results secured.

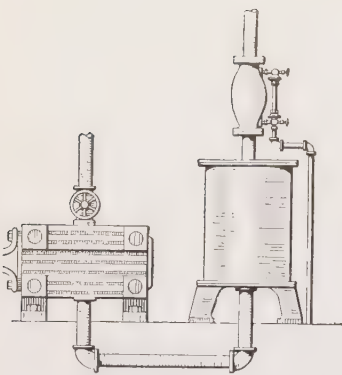


FIG. 1

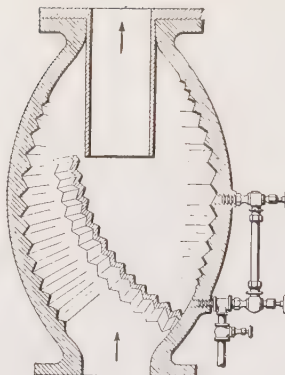


FIG. 2

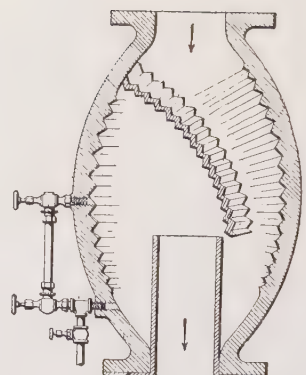


FIG. 3

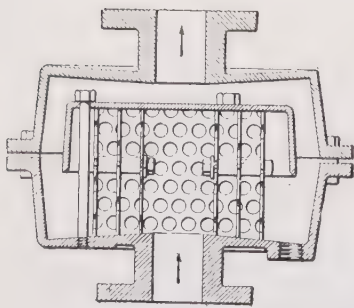


FIG. 4

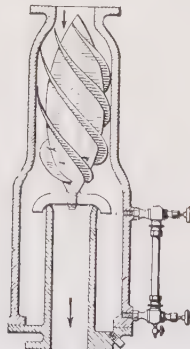


FIG. 5

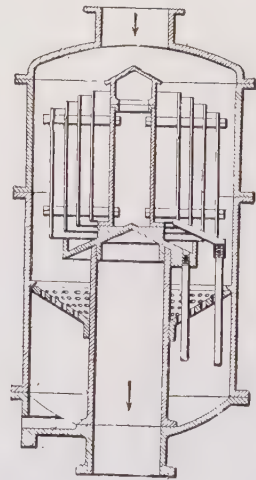


FIG. 6

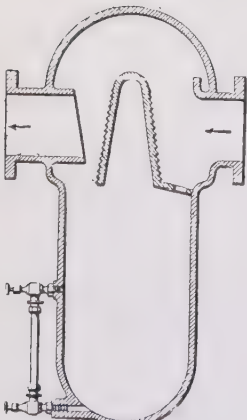


FIG. 7

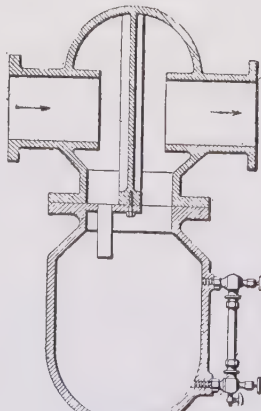


FIG. 8

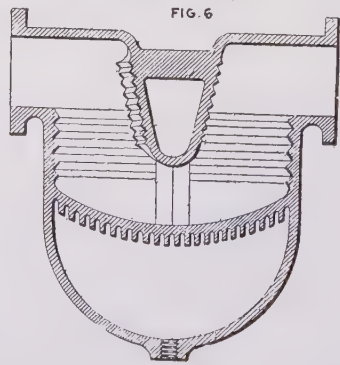


FIG. 9

Fig. 1—Separator placed above the heater gave better results than when placed next to the engine. Fig. 2—Steam enters at the bottom of the separator. Fig. 3—Same type of separator design with steam entering at the top. Fig. 4—Another separator in which the steam should pass upward. Fig. 5—Steam flow is downward. Fig. 6—Steam can flow in either direction. Fig. 7—Horizontal separator, steam entering at the right. Fig. 8—Separator with inlet connection at the left. Fig. 9—Steam can flow in either direction.

Separators should be placed as their makers intended that they should be. A good illustration of this necessity is shown in the following. Steam should pass upward through Fig. 2 and downward through Fig. 3. If the direction of the flow in either case is reversed, the best results cannot be expected. Where this design of separator is ordered direct from the manufacturers and working conditions are specified, they will be sent accordingly, but as time passes and changes in the piping are made, they may be put out of service. Later on, when required for other places, they may be installed so that the direction of flow is not the same as formerly. This is more likely to happen because the castings are practically the same, but that does not prove that they are interchangeable.

Fig. 4 illustrates a separator that should be located as shown, with steam passing upward through it. Fig. 5 shows a design that is not so likely to be mistaken as some other types. The curved deflecting plates must perform the separating function when the steam first enters the separator, and the reservoir must be located at the lower point; hence, steam flows downward and the oil and water go out through a suitable drip pipe.

If steam and oil pass upward through the type of separator shown in Fig. 6, some of the oil will be taken out, but the results will be more satisfactory if the direction of flow is downward.

Fig. 7 shows a horizontal separator with the inlet at the right and the outlet at the left. Fig. 8 shows a similar device, but the direction of flow is from left to right hand. If good results are desired, these directions of flow must be followed, but if it is necessary to use either one for a direction of flow that is opposite to the illustrations, it may be done by turning the separator around. In this respect a horizontal differs from a vertical separator, as the former can be reversed at pleasure to meet the direction of flow. However, care should always be taken to have the steam enter as the makers intended.

Fig. 9 is designed for steam flowing in either direction, and it does not make any difference which way it is connected.

[W. E. S.]



Studies in Indian Sugar Cane, No. 4.*

Morphological Considerations.

(Abridged.)

By C. A. BARBER.

As we work with the sugar cane plant in attempting to guide its variabilities to suit our purposes, any precise information such as that furnished by C. A. Barber and his collaborators in India becomes distinctly helpful.

(1) EARLY STAGES OF SEEDLINGS AND SPROUTED CUTTINGS.

Before proceeding to the description of branching in the sugar cane, it will be advisable to get some idea as to the various stages by which the plant, as we see it, is built up. For this purpose I have put together observations and drawings, which have been made at different times during the past five years, on the germination of the cane seed and the sprouting of the sets, as these will form a useful basis for our study.

The seed of the sugar cane is extremely minute, the average length being 1.5 mm. and its breadth one-third of that amount. Strictly speaking, it is not merely a seed, but a fruit or caryopsis, for, as in all grasses, there is only one seed in the ovary, and its walls are fused with those of the fruit to an indistinguishable mass. The embryonic plant lies obliquely across one end of the seed, the rest being taken up by a mass of starch-bearing cells, the endosperm, a reserve of food for the early stages of growth. On comparing the relative sizes of germ and endosperm, the sugar cane appears to be poorly equipped with the latter, as, before the young plant protrudes from the seed-coats, it occupies in the vertical section nearly half of the space available. Considering the small size of the seed itself, there is thus very little food laid by for the initial stages of growth before it becomes independent; the cane seedling is excessively small and its growth is not nearly so rapid as the cultivated grains, and, indeed, as the grass weeds which infest the seedling pans. The sugar cane in fact reminds us of the proverbial "mustard seed" in the smallness of its seed and the comparatively enormous size of the full grown plant. As a natural result of this, the seed of the sugar cane cannot be kept for long, although our series of observations, carried on for some years, show that its vitality is greater than previously supposed, and is not the same in all varieties.

The general course of development may be gathered from the accompanying figures, firstly, of microtome sections through resting and germinating seeds (Pl. I), and, secondly, of drawings made from outside (Pls. II, III, and IV). There is little in these Plates which calls for special attention, as the general course agrees with that in grasses and has been sufficiently described in textbooks. In the cases of *Karun* seedlings which have been examined (Pl. III),

* From Memoirs of the Department of Agriculture in India, Botanical Series, Vol. X, p. 46.

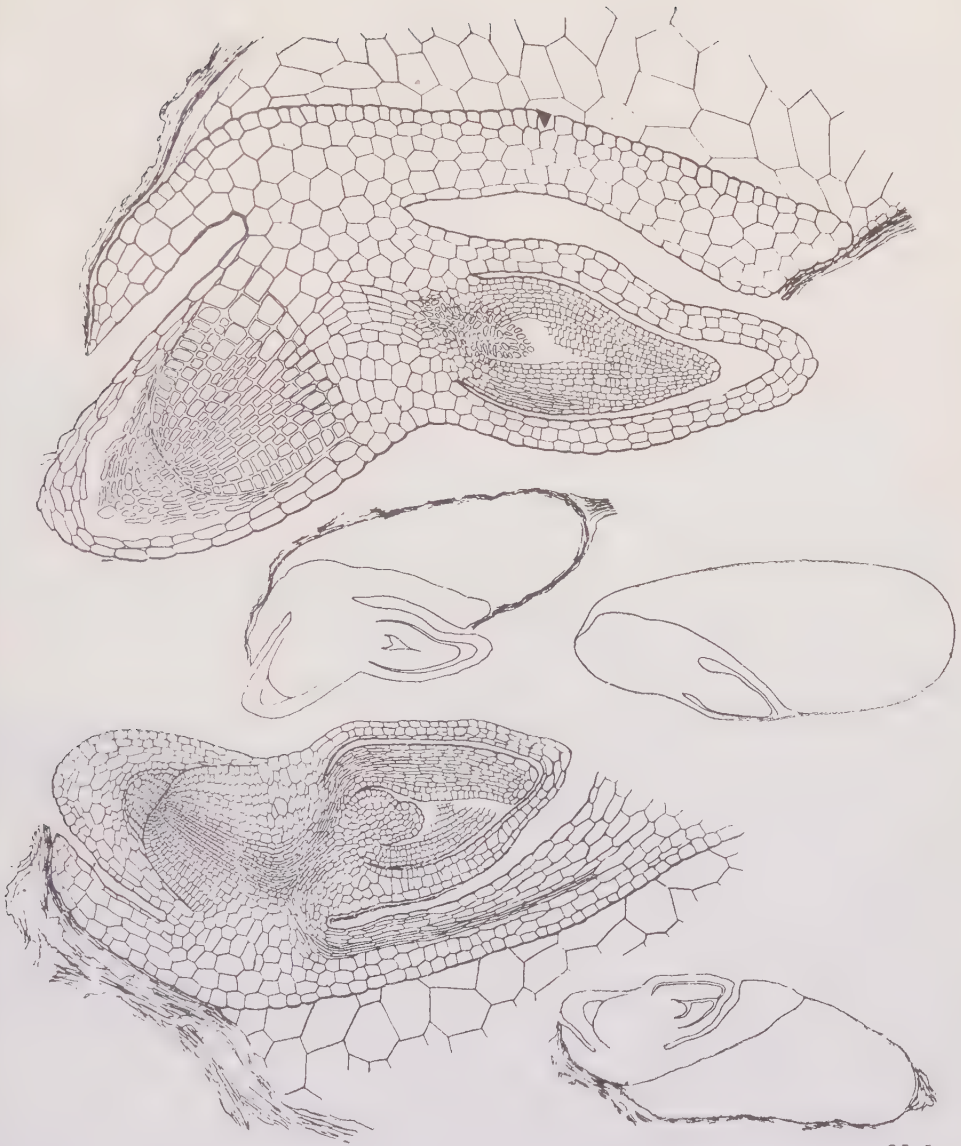


Plate I. Microtome sections through resting and germinating seeds of sugar cane. Madras Seedling No. 6.

there is an elongation of the plumule axis below the first leaf, similar to that in the wheat, presumably designed to place the young plant clear of its seed-coats and near to the surface of the ground, for the purpose of tillering, and I have reproduced a drawing from Percival's *Agricultural Botany* to make this clearer. But in the *Karun* seedlings a thickish root is given off from this elongated part of the stem which I have not seen figured elsewhere.

The purpose of this early root formation appears to be obvious enough, namely, to reinforce at the earliest possible moment the small amount of available stored material at the disposal of the young plant. The radicle with its

first root has, as usual, a merely temporary existence, or lingers for some time as a minute fiber which can have little effect in aiding the plant in its growth. After this preliminary arrangement of the parts of the seedling has been concluded, the plumule develops its leaves in rapid succession and, near their bases, a series of thick adventitious roots are soon produced; but the seed-coats, with the plug-like sucker, the elongated plumule axis and its first adventitious root, remain attached to the plant for a considerable time, as they have been detected in a *Karun* seedling already five inches above ground. Different stages in this development are given on Plates II, III, and IV.

The leaves are formed in one plane, alternately on either side of the stem, and the whole young plant may thus be pressed flat with all its parts spread out. At a very early stage of development a bud is formed in the axil of each leaf, so that branches, as well as leaves, all arise in the same plane. The formation of successive leaves, one at a time, has the effect of dividing the stem into a series of segments, each provided with one leaf and one bud. These segments are usually termed joints, and it is the practice to regard the joint as bearing its leaf and bud at its lower end, being thus terminated above and below by a leaf, and, when this has withered and fallen, by the sharp ridge or leaf scar which completely surrounds the stem. The region where the joints are separated is termed the node or knot, as it is usually more or less swollen, and the joint as defined above thus becomes the internode.

An appropriate arrangement of the fibrovascular bundles within the stem has meantime taken place, and this can be very well seen in longitudinal sections; namely, while the bundles run parallel with the length of the stem in the internodes, they form an intricate, webbed mass at the node, and branches are given off to the leaves and roots at this point. This arrangement of the bundles takes place very early in the development, and it is thus easier to demonstrate the limits of the first formed joints by viewing them in a longitudinal section than from the outside (Pl. VI, fig. 1C). The region of root formation is at the base of each joint, above the origin of the leaf, and consists of a narrow ring of the surface where the nascent roots may be seen as two or three rows of dots; this is termed the root zone. In parts of the stem beneath the level of the ground these root primordia quickly grow out and, perforating the leaf bases, form a mass of roots which, with their branchings and root hairs, leave no particle of soil untapped. The first formed joints are extremely short, being in the form of narrow superposed discs, and the leaves borne by them are therefore very close together. The joints are, moreover, extremely thin at first, but increase in thickness upwards, the successive leaves and roots providing material for their expansion, so that, as in many Monocotyledons, a longitudinal section of the stem at the base shows its form to be that of an inverted cone (Pl. IV, fig 1d). The leaves, growing much more rapidly than the stem, increase in width at the base and encircle a larger portion of the circumference of the stem until their edges overlap.

The further development of the plant proceeds on strictly similar lines. The main points to be held in view are the upward increase in thickness of the stem, the protrusion of the buds from the leaf axils, the increasing number and thickness of the roots developed on successive joints, the continual lengthening

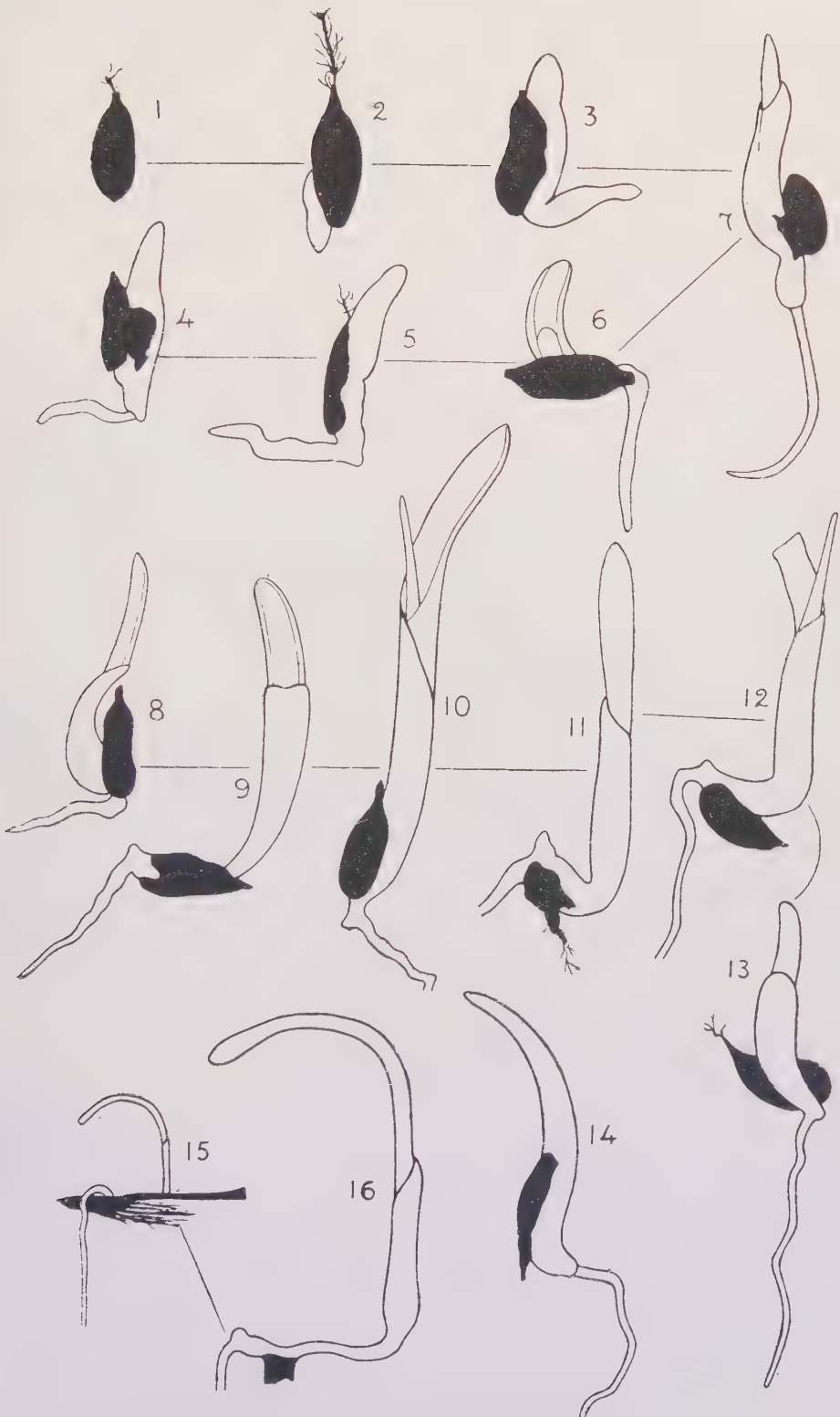


Plate II. Germinating seedlings of Kassoer; figs. 1-7, four days old; figs. 8-13, eight days old. Louisiana Purple, fig. 14, six days old. Madras Seedling No. 2, figs. 15 and 16, thirteen days old.

and widening of the leaves, so as not only to completely encircle the stem, but also to enclose the younger parts in a set of enveloping sheaths, and, later on, the gradual lengthening of successive joints, so that the growing plant is raised above the surface of the ground.

Immediately this occurs the stimulus of moisture and darkness being removed, the formation of roots falls into abeyance, but the root eyes can be detected in the root zone from the outside throughout the length of the plant. The leaf, at first purely protective and consisting of leaf base or leaf sheath, on emerging to the light, soon develops a small green tip, the leaf blade or lamina, and this part rapidly increases in relative size until it forms the bulk of the leaf. But this leaf development is much more rapid than that of the stem, so that, when the growing point of the stem at length reaches the surface the leaves have already reached a very respectable size (Pl. III). The largest seedling (fig. 4) has a leaf already a foot in length, whereas the stem is as yet only one-third of an inch long.

The cane seedling four or five months old, viewed from above ground, usually shows a tall central shoot surrounded at its base by a number of smaller shoots emerging from the soil near it. These are the developed buds of the lower leaf axils. As the first joints of the stem are very close together, and each has its lateral branch, these shoots, being pushed out of their original plane from lack of room, appear all together as an irregular circle round the main shoot, but careful dissection shows that they all arise from different axils on alternate sides of the plant (Pl. IV). The growth of successive buds, however, varies a good deal, and their size at this stage bears no sort of relation to the time at which they were formed at the apex of the stem. Some buds remain quite small during the life of the plant, whereas others grow so rapidly that they soon overtake or even exceed the main shoot in length.

The branches pass through exactly the same stages as the parent stem, only differing from it in that they have a better start and take less time to develop into leafy shoots. They are thin at the place of origin, bear closely packed leaves on the short congested joints, have a bud in the axil of each leaf, and, as the leaves increase in length and expand their blades, the stems increase in thickness, the successive joints become longer, and the shoots as a whole emerge from the ground. As in the main shoot, the leaves at first grow much faster than the stem and, for a long time, the actual growing points of the stems remain below the ground, the height of the plant being judged by the length of the expanded leaves. This is readily explained by the fact that the growth of each shoot is largely dependent on the feeding power of its own leaves and, until these are fairly large, no real progress can be made, hence their early protrusion and proportionately rapid early growth. The relative size of the main shoot and its branches and the number of the latter vary much in the same batch of seedlings, all stages being observable between one strong cane, with or without a few small shoots at its base, and a bunch of shoots resembling a tuft of grass, in which it is difficult to distinguish between the main stem and its branches. The reason for this is not clear, for seedlings thus differing in their early stages are often not distinguishable in their degree of branching later on.



Plate III. Young cane seedlings. Figs. 1-4, Karun, from one inch to one foot in height.
 Fig. 5, germinating grass seedling. Fig. 6, young barley plant.

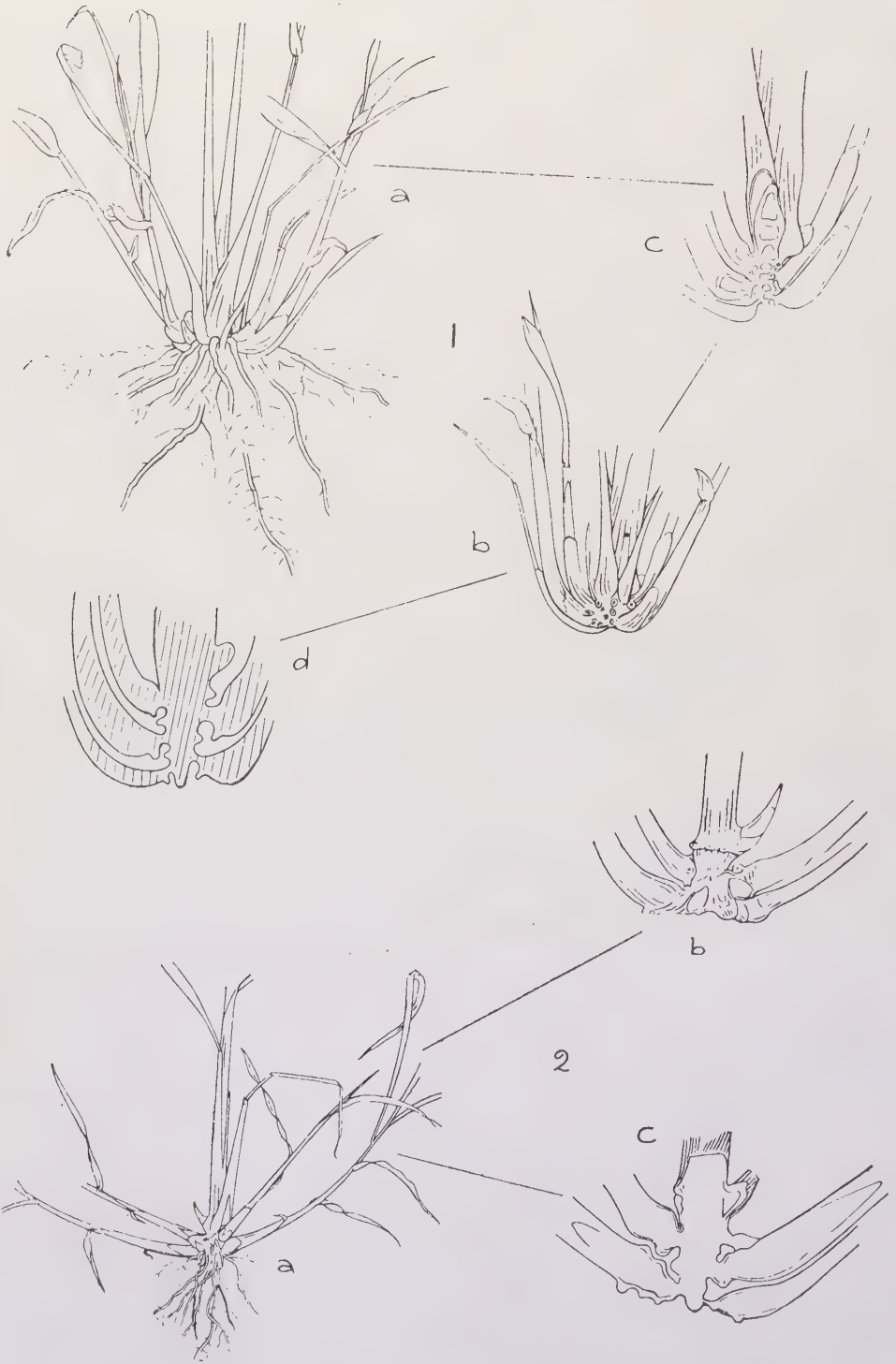


Plate IV. Cane seedlings about four months old. Fig. 1, Poovan seedling dissected (113 days old). Fig. 2, seedling of *Saccharum spontaneum* (133 days old).

At a somewhat later stage the lateral shoots, each as fully provided with buds as the parent stem, may also branch, giving rise to branches of the second degree, and this process may continue to several further degrees, this depending to a large extent on the parentage of the seedlings. Such shooting of the buds on lateral branches is not, however, usual until the plant has reached a further stage of development, unless, indeed, one of the branches receives an accidental injury low down, when its place is often taken by one of its uppermost buds.

The chief points to bear in mind concerning the branching of seedlings are that every joint has its leaf and, protected by it, a bud; that both joint and bud have the power of forming independent roots if the necessity should arise; and that any of these buds may remain quiescent or dormant throughout its life, or may shoot out at once or at a later stage in the growth of the plant as a whole. There is thus ample provision at hand for all the needs of the plant, whatever circumstances may arise. However severe the treatment above ground, there is a reserve of branches ready to be developed below, and, if one of the branches is either accidentally or purposely cut off, its place is taken by the emergence of one of its buds; and, if such a cut branch is placed in the ground, it is capable of sending out its roots under the stimulus of moisture and darkness, protruding its buds and developing into an independent plant.

Advantage has been taken of these facts in the planting of the sugar cane in the field. Cultivated sugar cane is propagated from cut pieces of the stem and is always likely to be. Seedlings, although undoubtedly a much cheaper form of reproduction, do not inherit the good qualities of their parents uniformly, and many of them, even of the best parentage, are quite worthless from the sugar producing point of view. Although extremely easily reared in many cases, they require more individual attention than is justified under crop conditions, and they take longer to mature. While in South India canes grown from cuttings take, on the average, twelve months to mature, seedlings become full grown only when they are about eighteen months old. Besides this, there are many good kinds which do not produce seed at all, either because of infertility or the total absence of flowering. In vegetative reproduction the good qualities of the variety are rigidly handed down from generation to generation, although there appears to be a gradual diminution of vigor as the years pass.

The vegetative method of reproduction is rendered easy, as explained above, in that each joint is furnished with its bud and a number of root primordia, and both of these require little stimulus to grow out. The condition of the bud may be compared with that of the germ in the seed, in that it is placed in immediate connection with a mass of readily assimilable nutriment in the joint to which it belongs. It is, however, much more fully developed than the germ, and it takes little time, under suitable conditions of moisture and warmth, for it to produce a mass of roots and leaves. The development of this bud need not detain us here. It is practically identical with that of the shoots described above, being merely a branch of the plant of a higher order. A series of stages are shown in Plates V and VI.

In planting, the whole cane is sometimes laid in a furrow, lightly covered with earth and watered; in many places only the upper, immature parts of the cane are used, and these, called "tops," are placed slanting in the ground; but

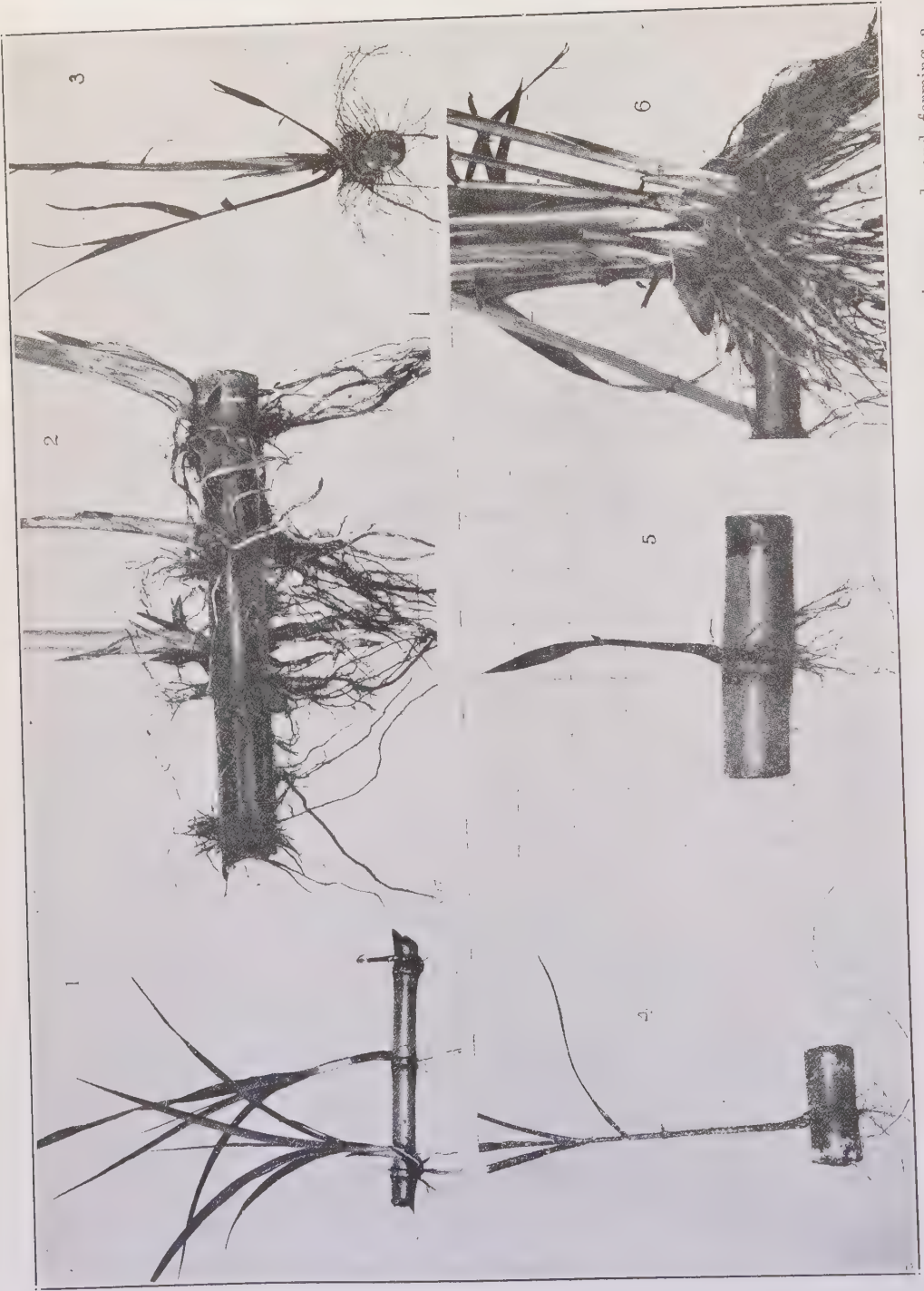


Plate V. Sprouting set plants. Fig 1, *Saccharum arundinaceum*, showing bud beneath the set curving upwards and forming a healthy shoot. Fig 2, Gillman, 25 days old. Fig 3, Red Mauritius, 37 days old. Figs 4 and 5, Vellai, 37 days old. Fig. 6

in India, as a rule, the whole cane is cut up into pieces called "sets," each of which has a definite number of joints with healthy living buds. Almost all canes germinate readily from sets, and, in India, they seem to produce healthier and stronger plants than the tops; but cases have been met with, as in *Scema* of the Godavari District, where sets are generally infertile and tops have to be used. The sets in South India usually contain three joints; germination takes place more rapidly than in North India, and if the field has not sprouted within a week or ten days it is customary to plant again. In North India the climate at the time of planting is very cold, and not infrequently a month elapses before the shoots appear above ground.

When, in a warm climate, the sets are placed horizontally in shallow trenches and watered, they at once send forth roots and the buds burst. Although, possibly, in ideal planting, it would be best to place the sets so that the bud plane lies parallel with the surface, this is not generally attended to nor essential, for the shoots are negatively geotropic and quickly find their way round the set to the surface of the ground.* The root eyes protrude and form a circlet of fibers round the set, those beneath growing much more strongly than those facing upwards, and these roots supply the stream of water which washes the nutriment stored in the joint to the developing bud. But very soon the lower joints of the new shoot form their own roots—thicker, whiter, and longer. When this occurs the shoot forms a new, independent plant, and the decayed joint from which it has arisen is left behind, much as the cast-off seed-coats in a germinated seedling. Connection with the plants developed from the other buds in the same set is thus entirely severed. Lateral branching takes place very early in the young plant, and these branches also produce their own roots, and, in a couple of months, the set plant has attained to the size and form of the six months seedling and is growing much more rapidly.

The canes of different ages in the same clump are sometimes very different. This has been already noted in the remarks on early and late canes. But this difference is much greater in seedlings than in canes grown from cuttings. It is true that all the canes seem to be similar in some cases, but in others it is not unusual to note thin, yellow, sprawling canes developed first, these succeeded by reddish tinged slanting canes, while the latest formed are thick and dark purple; and all sorts of such color variations may be detected, as well as variations in thickness and erectness. We do not as yet know whether this variability is handed on to the next generation, when the seedling is grown vegetatively, or whether only one of the forms of cane noted is characteristic of the future crop cane, but experiments are being conducted to determine this point, which is of considerable moment for the proper selection of seedlings.

* Since writing the above our attention has been drawn to the following. Kulkarni, in Dharwar, has made a series of experiments in planting sets, each with one bud only, and the set placed so that this bud is upward. He allowed only the mother shoot to grow and its branches were carefully removed. He claims that, by this means, sprouting takes place one week earlier, all the canes ripen together and a larger number are obtained per acre. (Kulkarni, M. L. Experiments in planting sugar cane sets with single eye-buds, etc. Agr. Jnl., Ind., Special Science Congress Number, 1918.)

(2) PERIODS OF GROWTH.

The great bulk of the Order Gramineae consists of grasses, and it will be of interest briefly to consider their mode of branching, in order to see in what respects the sugar cane resembles them—for the sugar cane has often been described as a gigantic grass. There are two well marked phases of development in grasses: the first, in which the plant remains low and adds shoot to shoot until a dense bush is formed, in which the shoots are often inextricably intertwined and point in all directions; and, second, in which the ends of certain of these branches become erect, rapidly increase in length and proceed to form the spikes of flowers and ears of grain. In the first stage the energy of the plant is devoted to multiplying its number of shoots, chiefly by the branching of the underground portion; in the second, branching ceases and the energy is diverted to pushing the branches high into the air and the formation of flowers where they can be readily fertilized, and the seed where it can be scattered abroad.

In the sugar cane this division into periods of growth is to a certain extent hidden, in that, both in seedlings and set plants, each shoot, as soon as it is formed, pushes into the air and grows steadily upwards to form the aerial stem or cane. Flowering is a matter of secondary importance, and has largely fallen into desuetude from long propagation by the vegetative method. This is especially so in North India, where flowering is rare; but in the Peninsula, as in most tropical countries, flowering takes place regularly towards the close of the growing season, and the fields then present a mass of feathery plumes over the whole area. It may be noted, in passing, that the time of flowering does not coincide with that of reaping the crop, as these two periods are induced by very different climatic conditions. Flowering occurs at Coimbatore during the period of greatest rainfall, in October and November, and indeed seems to be greatly influenced in its profusion by the amount of rain falling during the year; while the cane is harvested when the juice is richest, and this occurs in February and March, after the cold season, when the air becomes hot and dry.

The formation of new shoots at the base of the cane plant proceeds during the whole of the growing period, but there is no doubt that it is much more active at the commencement of growth, for the rapid formation of canes is not really taken up until the plant is six or seven months old. And this separation of the branching and lengthening periods of the plant is in certain cases emphasized by local conditions of growth. In South India the sets are planted at the commencement of the hot, dry weather, when the harvest is reaped, sugar cane being everywhere an irrigated crop. In the Godavari District, the young plants, after growing for a few months, receive a severe check, in that the irrigation channels are closed every year in May for cleaning, and for some six weeks irrigation is in abeyance, and the plants depend on such scanty showers as fall at this time. During this period the branching of the underground parts goes on steadily, although little is added to the height of the plants. In fact the plants often appear to grow shorter, in that they are attacked by shoot-borer and many of the shoots are destroyed. But the ryot views the matter with equanimity, because he knows that this pest merely causes the lateral branches to be

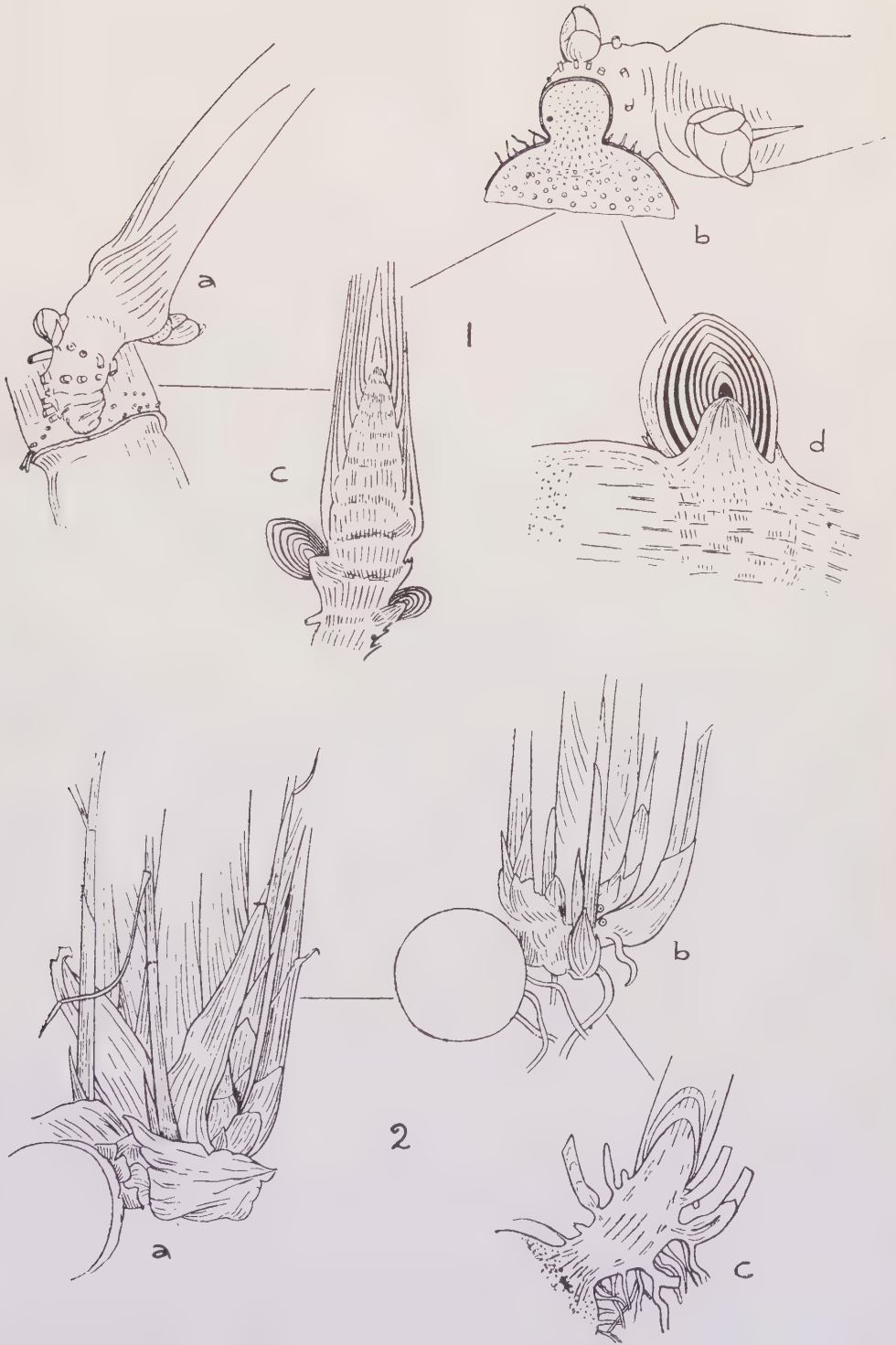


Plate VI. Dissection of sprouting set plants. Fig. 1, Gillman, one month old. Fig. 2, Red Mauritius, two months old.

developed in larger numbers, and he asserts that he gets a better stand of canes when there is an attack of moth borer. It is probably of no great disadvantage for the shoots to be checked when there is no water to continue their growth; but cases are also met with where whole fields are destroyed by the pest, or ugly gaps are seen in the plantations. The branching period is lengthened and made more pronounced in this case, which in some respects is analagous to winter-sown wheat in Europe.

A similar lengthening of the branching period is to be noted as the result of certain diseases of the cane. In the neighborhood of Coimbatore, where many of the wells contain brackish water, sometimes the plants, especially ratoons, never reach the cane-forming period, but continue throughout the season to develop new shoots with narrow leaves, which do not grow in length, but branch again, until, at crop time, nothing is seen but a number of low, dense, grassy bushes. A case was met with by the author on new, rough land, near the emergence of the Amravati River from the hills, where, in a couple of acres fourteen months old, only a few canes were observable, and the field closely resembled one of *Guinea grass*. It is needless to point out the similarity of this growth to that induced by *Sereh* in Java and certain diseased clumps observed years ago in Barbados, where all the buds and roots of the short canes shoot out, till a dense mass of grassy leaves is produced in place of a few tall, healthy canes.

Another feature in the branching of grasses may be noted here. It is usual to divide them, according to their mode of growth, into tufted grasses and sod-formers. In the latter, underground branching assumes an intense form, each bud piercing the base of its enveloping leaf sheath and again branching itself, until, with the masses of roots formed at the bases of the joints, the soil is permeated so thoroughly that it can be cut into coherent slabs, as in lawns and permanent pastures. The individual plants are closely interlocked and it becomes very difficult to dissect them out without injury. The main feature in these grasses is the great development of underground runners or stolons, the ends of which emerge and bear tufts of leaves for the purpose of nutrition, while their place is taken by buds near the upward bend, and the underground part is thus formed of a mass of sympodia. Flowering takes place at a certain season, but this does not interfere with the underground branching. In the tufted grasses, on the other hand, after a limited period of underground branching, a number of erect shoots are formed, which in due course proceed to the formation of flowers and grain. The buds in this case do not pierce the bases of the enclosing leaf sheaths, but grow up inside them, emerging where the sheath joins the lamina, only splitting the leaf sheath by their increase in thickness. The individual plants are easily separable, do not interlock, and each forms a more or less distinct tuft.

It is at once obvious that the sugar cane belongs to the latter class, as do the usual cultivated cereals. This also applies to the wild *Saccharums*, *Munja*, *Narenga*, *arundinaceum* and *spontanæum*, grown on the Cane-breeding Station. The two former are typical tufted grasses; no cane is formed and the flowering shoots are ephemeral structures, drying up after the seed is ripened. In *Saccharum arundinaceum* and *Saccharum spontanæum*, solid canes are formed. *Saccharum spontanæum*, although undoubtedly a tufted form, produces long un-

derground shoots which emerge at intervals and thus spread the plant over a considerable area. It is difficult in growing this species, either from seed or from sets, to confine it to its bed, and the neighboring paths are soon invaded. We may thus imagine an approach to the sod- former here. The nearest approach to sod-formation in *Saccharum spontaneum* which we have observed is on the banks of the Irrawaddy, where sandbanks are protected from being washed away by an interlacing mass of roots and runners, which forms a solid cap a foot in thickness. The formation of underground runners is occasionally met with in cultivated canes. It is commonest in the Sarethia group, the most primitive class of indigenous Indian canes, and, apparently, the nearest in descent to the wild *Saccharum spontaneum*. In other classes runners usually are formed only where space is needed for the free development of a large number of cane stems. Thus we meet with them most frequently in the Mungo and Pansahi groups, which are characterized by much branching. In these cases long, thin joints are intercalated between the normal short, thick ones of commencing shoots, and in the dissections these are always noted.

(3) THE BRANCHING OF THE CANE ABOVE GROUND AND ABNORMAL BUD FORMATION.

Branching of the cane plant below ground is a well marked feature in all varieties. Above ground, in the light and in the absence of the stimulus of moisture, the buds usually remain inactive during the period of maximum growth. But the shooting of aerial buds is by no means uncommon, and is of some disadvantage from the crop point of view. It has been noted that some varieties, such, for instance, as B. 208, shoot more readily than others; but there are a number of circumstances which render all canes more or less liable to this defect. Any injury to a growing cane will tend to cause the buds below the injured place to shoot out because of the damming up of the current of water and nutrition. This is often seen where stem-borer is at work. The joints immediately above the attack are shorter and thinner than the average, and large shoots are often observed coming from the nodes below the borer hole. Canes which have lodged or fallen will frequently develop a mass of shoots all along the prostrate part; over-ripe canes and such as have flowered usually form a mass of shoots in the upper part if allowed to continue growing; lastly, the local climate has a very distinct influence in the matter. Thus, when the same canes are grown at Pusa and at Coimbatore, they behave very differently as regards shooting. At Coimbatore, which is in a semi-arid region, shooting of the canes is very rare; while at Pusa, with its abundant supply of subsoil water, approaching the surface in the rains, a great mass of green is sometimes seen all the way up the stem, even in erect canes, long before the reaping season.

This shooting of the buds is generally correlated with a more or less active protrusion of the root eyes. In places where there is a marked difference in the humidity and temperature at different periods of the cane's growth, this difference is often permanently marked on the different joints of the cane stem. Thus, at Rajshahi, in North Bengal, it is easy at crop time to determine what joints had been formed during the hot, dry summer months, and at what stages

the rains attained their maximum and ceased to flood the ground. The rooting and shooting of the canes in damp climates is often avoided by trashing, or pulling off the adherent but dying leaves, and it would be worth while considering the desirability of trashing canes in North India during the rains, in places where these defects are most marked.

Besides the normal branching of the cane, due to the protrusion of the ordinary buds on the joints, cases of abnormality are not infrequently met with, caused by irregularity in the bud development. Here and there canes have been met with where the joints have been altogether devoid of buds, and Kaghze has been marked in the Coimbatore collection as especially liable to this deformity. Here obviously no branching can take place. In others, double or triple buds have been met with in place of the single bud, and in the usual position. Where double buds occur they are not infrequently the prelude to a dichotomous splitting of the cane into two equal halves, each of them proceeding to grow normally. On passing down the stem, such double buds are seen to be preceded by buds of abnormal width, accompanied by a flattening of the stem. Such cases have been very clearly described by Jeswiet,¹ and need not be further dealt with here. Among the cases of triple buds, one was noted as being extremely regular in its development, and it was preserved because of its interesting nature. After four years of reproduction the same abnormality can be seen, showing that it is a hereditary character of the seedling when propagated by cuttings.

But the most striking and frequent case of abnormal bud formation is when they are irregularly produced in different parts of the stem without any regard to the usual position. They are often met with in the root zone, for here there is, more or less permanently, meristematic tissue, but they may also appear at almost any part of the joint. They may arise direct from the outer layers of the stem, but more usually they are preceded by the formation of an irregular mass of callus, over which the buds are distributed unevenly, varying from mere pin points of tissue to fully formed buds with scaly leaves. Curious monstrous forms are thus produced. They would appear to be commoner on seedlings of certain parentage, although they have been found sporadically in almost all the plots, thus conveying the suggestion that the formation of cane plants from seed is no longer governed by the strict rules applicable to seed-bearing plants. In 1917-18 the Khelia plot of seedlings was thus marked out as containing numerous examples of this deformity. The cases thus far mentioned do not seem to have their origin in any injury to the cane tissues, but, in other cases, the callus results from the hole of a stem-borer, the breaking of a cane, or the curious "cuts" above the bud in the groove, to which attention was drawn in the Journal of Heredity of February, 1916. These cuts have been found in many of our seedlings and cane varieties on the farm, and appear not to be the result of any insect or other attack, but on differences in tension of the superficial layers of the stem. They have been found also in seedlings of *Saccharum spontaneum* in some quantity. A large number of other abnormalities have been noted in the seedlings and varieties grown on the station, and the study of these would undoubtedly prove of interest from the morphological point of view.

¹ Jeswiet, J. Beschrijving der soorten van het suikerriet. Erste bijlage. Morphologie van het suikerriet. Archief v. d. Suikerind. in Ned. Ind., Maart, 1916.

Sugar Prices

96° Céntrifugals for the Period

March 15, to June 15, 1922.

Date	Per Pound	Per Ton	Remarks
March 16, 1922..	3.98 ¢	\$79.60	New Cubas.
" 17	4.045	80.90	Porto Ricos 3.98, new Cubas 4.11.
" 23	3.98	79.60	New Cubas.
" 24	3.86	77.20	New Cubas.
April 3	3.89	77.80	New Cubas 3.98, Porto Ricos 3.80.
" 4	3.98	79.60	Porto Ricos.
" 5	4.11	82.20	New Cubas.
" 13	4.04	80.80	New Cubas.
" 17	3.86	77.20	Porto Ricos.
" 20	3.805	76.10	Porto Ricos 3.86 and 3.75.
" 21	3.75	75.00	Porto Ricos.
" 24	3.86	77.20	Porto Ricos.
" 25	3.92	78.40	Porto Ricos 3.86, new Cubas 3.98.
" 26	3.98	79.60	New Cubas.
" 27	4.0433	80.866	Philippines 3.98, new Cubas 4.11 and 4.04.
" 29	3.92	78.40	Porto Ricos.
May 1	3.995	79.90	New Cubas 3.98, new Cubas 4.01.
" 4	3.98	79.60	New Cubas.
" 5	3.87	77.40	Philippines 3.86, Porto Ricos 3.88.
" 6	3.98	79.60	New Cubas.
" 9	3.9825	79.65	Porto Ricos 3.86 and 3.92, new Cubas 4.04 and 4.11.
" 10	3.9667	79.334	New Cubas 4.04, Porto Ricos 3.98 and 3.88.
" 11	3.98	79.60	New Cubas 4.04, Porto Ricos 3.98, Philippines 3.92.
" 12	4.04	80.80	New Cubas.
" 22	4.00	80.00	Philippines.
" 24	4.1608	83.216	Philippines 4.125, new Cubas 4.17, Porto Ricos 4.1875.
" 25	4.17	83.40	New Cubas.
" 26	4.20875	84.175	New Cubas 4.23, Philippines 4.1875.
" 31	4.265	85.30	New Cubas 4.23 and 4.30.
June 2	4.30	86.00	New Cubas. Summer Saturday market holidays begin tomorrow.
" 9	4.6175	92.35	Philippines 4.625, new Cubas 4.61.
" 14	4.6175	92.35	Cubas.
" 15	4.50	90.00	Porto Ricos.

